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A PRACTICAL TEST FOR COKING COALS.[1]

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While engaged recently in studying the physical properties of coal, especially with reference to the color of the streak and powder, the writer observed that some coals adhered much more strongly to the mortar while being pulverized than others, and that the best coking coals were the ones which adhered most, while the non-coking coals adhered very slightly or not at all.

This gave promise of affording a simple and inexpensive method of distinguishing coking from non-coking coals without the necessity of a trial in an improvised rick, or the better but more expensive way of sending the coal to a coking plant for a test in a regulation oven. For a long time geologists, chemists, and practical coal miners generally have been searching for such a test, but up to the present time without success.

In view of these facts the adherence test seemed to be promising, and the writer began experimenting systematically with all coals available in the study collection of the United States Geological Survey. Fortunately this collection comprises a large number of samples of all kinds of coal from lignite to anthracite, and includes some of the best known coking coals of the country.

In all 150 samples of coal were tested, and the results seemed to be of sufficient economic importance to warrant publication. The writer therefore takes this opportunity of presenting in brief

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form a statement of the method of conducting the test and the results obtained on the samples referred to above. He does not regard his conclusions as final, but merely gives the facts for what they are worth, hoping that others will make application of the test and thereby determine its value in a practical way.

The method of conducting the test is as follows: Pulverize in an agate mortar a small quantity of the coal to be tested until it will pass through a 100-mesh sieve. Pour out the pulverized coal and observe the condition of the mortar and pestle. With some coals the mortar and pestle will be deeply covered with a coating of coal dust which adheres so strongly to the agate surface that it is removed with difficulty; with other coals there will be only a thin film of coal dust adhering to the mortar and pestle; while with still others both mortar and pestle will be nearly as clean after the coal is pulverized as they were before the operation began.

The degree of adhesion seems to coincide with the coking qualities of the coal. If it adheres strongly the coal will probably make excellent coke. If it adheres only slightly the coal possesses the coking qualities to only a slight extent, if at all, and if the mortar shows no coating of dust, the coal is to be regarded as non-coking.

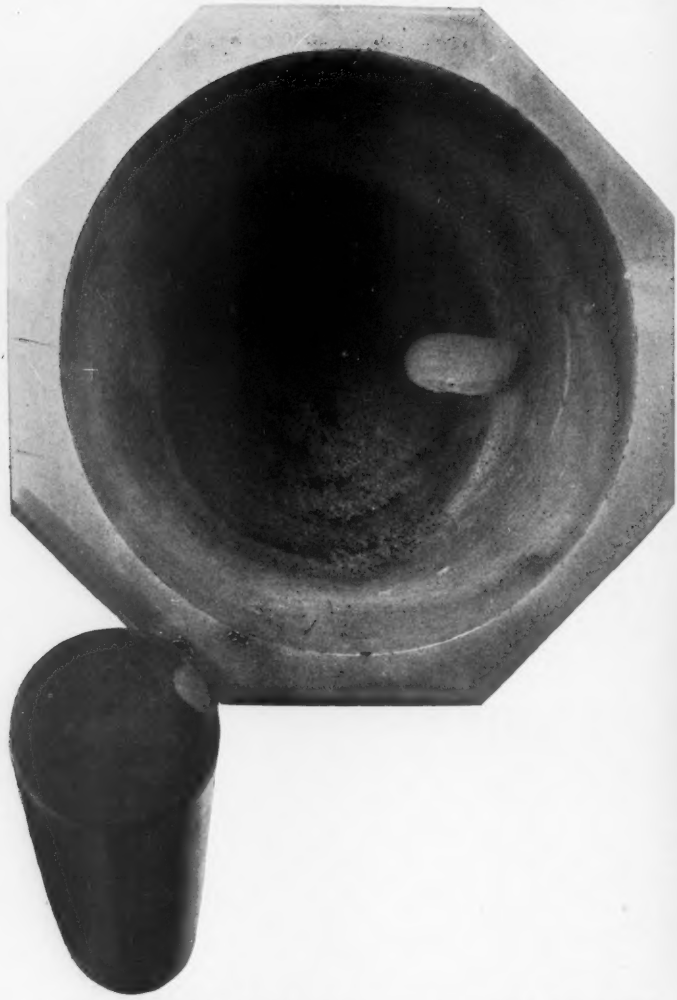
The accompanying plates show how a non-coking, a poorly coking, and a good coking coal behave in the mortar after a charge of each has been ground and removed. Plate V shows the mortar after a coal from Brazil, Ind., had been ground. This is a block coal and is considered to be a good type of non-coking coal. It will be noticed that the amount of adhesion is slight.

Plate VI shows the mortar after a charge of Cambria, Wyoming, coal had been ground. It adheres fairly well. Coke from this coal has been used in smelters in the Black Hills, but it is not first class coke and consequently the product is not in great demand.

Plate VII shows the mortar after a sample of good coking coal from Straight Creek, Kentucky, had been ground. It adheres strongly and shows a thick film of sooty material covering a

PLATE V

CONDITION OF MORTAR AFTER NON-COKING COAL HAD BEEN PULVERIZED



CONDITION OF MORTAR AFTER A SLIGHTLY COKING COAL HAD BEEN PULVERIZED

CONDITION OF MORTAR AFTER A GOOD COKING COAL HAD BEEN PULVERIZED

circular spot in the center of the mortar where the grinding was done. The intensity of adhesion is noticeable especially when one tries to clean the mortar, for it requires considerable rubbing to entirely remove the coal.

In addition to the adhesion of the fine particles to the mortar, some coals show a tendency to pack together or cohere. Although this phenomenon appears to be limited to coking coal, it is thought to depend more on the moisture content in the coal than on its coking quality, but sufficient work has not been done to determine this point.

The results obtained in testing the miscellaneous samples noted above are given in the following table. The scale of adhesion used in describing the tests is as follows: *none, poor, medium, good,* and *excellent.* It shows that the coking coals range from between medium and good, to and including excellent, and that non-coking coals range from medium to none. Those marked medium are doubtful and may or may not possess coking qualities. If they do produce coke it is probably of such a poor quality as to be worthless for commercial purposes.

TABLE SHOWING RESULTS OF COKING TESTS ON 150 COALS.

STATE NAME OF MINE OR OPERATOR	LOCALITY	KIND OF COAL	COKING QUALITY	ADHERENCE TO MORTAR WHEN GROUND	REMARKS
ALABAMA					
Chicasaw No. 5	Carbon Hill	Bituminous		Medium to good.	
Mine No. 8	Horse Creek	"	Is coked	Good.	
[1] Woodward Iron Co. No. 2.	Dolomite	"	"	Excellent.	
Lookout Fuel Co	Lahusage	Semi-bituminous	Coked in lab	Good	Packs.
ARKANSAS					
[2] Red Rock	Burmah	"		Medium to good.	
[3] Spadra Anth. Coal Co	Spadra	Semi-anthracite		" "	
[3] S. Anth. Coal Co	Russellville	"		" "	
CALIFORNIA					
Stone Canyon Coal Co	Stone Canyon	Bituminous		Poor.	
COLORADO					
Colo. Anth. Coal Co	Deep Creek	Anthracite		None.	
Sweeney "Tunnel"	Lay	Bituminous		Poor.	
Collom Mine	Axial	"		"	
Coryell Mine	Newcastle	"		"	
Coal Basin Mine	Coal Basin	"	Is coked	Excellent.	
Book Cliff Coal Co	Grand Junction	"		Poor.	
Rollins Mine	Delta	Subbituminous		None.	
Fairview Mine	Delta	"		None.	
Watson Mine	Cedaredge	"		None.	
Mosley Prospect	Somerset	Bituminous		Poor.	
Cooperative Mine	Paonia	"		Medium.	

[1] One piece of nut size taken from a two-quart sample adhered very slightly, whereas another from the same sample adhered strongly, indicating a good coking coal. It seems probable that the bed is made up of different grades of coal, some of which make very much better coke than others.

[2] This coal is the same as the Hartshorne coal of Oklahoma, which is coked a few miles west of the Arkansas state line.

[3] These coals behave alike and in appearance are very much the same. They are brittle and high in fixed carbon. When ground they behave very much like charcoal, soiling the mortar in the same way. Apparently they are on the boundary line between coking and non-coking coals.

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STATE				ADHERENCE TO MORTAR	

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TABLE SHOWING RESULTS OF COKING TESTS ON 150 COALS.

STATE NAME OF MINE OR OPERATOR	LOCALITY	KIND OF COAL	COKING QUALITY	ADHERENCE TO MORTAR WHEN GROUND	REMARKS
COLORADO—*Continued.*					
King Mine	Bowie	Bituminous	Is coked	Medium to good.	
Phillip Mine	Crawford	Anthracite		None	
Newman Mine	Hotchkiss	Bituminous		"	
Simpson Mine	Lafayette	Subbituminous		"	
Calumet Fuel Co	Durango	Bituminous	Coked in lab	Medium to good.	
ILLINOIS					
Clover Leaf Coal Co	Coffeen	"		None.	
Capital Coal Co	Springfield	"		"	
Donk Bros. C. & C. Co	Donkville	"		None	High in ash.
Peabody Coal Co	Marion	"		Poor to medium.	
INDIANA					
Parke Co. Coal Co	Heckland	"		Medium to good.	
Johnson Coal Co	Williamsport	"		Poor to medium.	
Crawford Coal Co	Brazil	"		None	Brazil block coal.
Mutual Mining Co	Cannelburg	"		None	Cannel coal.
IOWA					
Johnstone Coal Co	Clayworks	"		None	Cannel coal.
Inland Fuel Co	Chariton	"		Poor.	
Centreville Block C. Co	Centerville	"		"	
Anchor Coal Co	Laddsdale	"		None.	
KANSAS					
[1] Western C. & M. Co	Yale	"		Excellent.	
[1] M. K. & T. Ry. Co	Mineral	"		Good.	
KENTUCKY					
East Kentucky C. Co	Lesley	"		Poor	Cannel coal.
Prospect	Jackson	"		Poor	Cannel coal.
Prospect	Big Black Mtn	"		Good	Splint coal.

[1] According to the tests these coals should coke, and it is reported that coke has been made from this bed in the vicinity of Pittsburg, Kans.

TABLE SHOWING RESULTS OF COKING TESTS ON 150 COALS.

STATE Name of mine or operator	Locality	Kind of coal	Coking quality	Adherence to mortar when ground	Remarks
KENTUCKY—*Continued.*					
Straight Cr. C. & C. Co.	Pineville	Bituminous	Is coked	Good.	
Central C. & I. Co.	Central City	"	Coked in lab.	Poor to medium.	
St. Bernard Min. Co.	Earlington	"	Is coked	Medium to good	Coal bed No. 9.
Wheatcroft Coal Co.	Wheatcroft	"	Coked in lab.	Medium to good	Coal beds Nos. 9, 11
MARYLAND					
Carlos Mine.	Carlos	"		Good	Pittsburg bed.
MICHIGAN					
[1] Consolidated C. Co.	Saginaw	"		Medium.	
MISSOURI					
Mendota Coal Co.	Mendota	"		None.	
MONTANA					
Kendrick Mine	Miles City	Lignite		"	
Hedges Mine	Miles City	"		"	
Weaver Mine	Miles City	"		"	
Dominy Ranch	Miles City	"		"	
Bear Cr. Coal Co.	Bear Creek	Subbituminous		None	Coal bed No. 2.
Bear Cr. Coal Co.	Bear Creek	"		None	Coal bed No. 3.
Bear Cr. Coal Co.	Bear Creek	"		Poor	Coal bed No. 4.
Washoe Copper Co.	Bear Creek	"		None	Coal bed No. 1.
International C. Co.	Bear Creek	"		None	Coal bed No. 5.
Northwestern Imp. Co.	Red Lodge	"		None	Coal bed No. 1½.
Northwestern Imp. Co.	Red Lodge	"		None	Coal bed No. 6.
Cliffe Mine	Giltedge	Bituminous		Poor.	
Lester Mine	Green	"		None.	
Spring Creek Mine	Lewistown	"		"	
Cooper Mine	Moore	"		"	
Havre Coal Min. Co.	Havre	Subbituminous		None	Resembles cannel c.

[1] The Michigan coals are generally regarded as non-coking, but from the results obtained in the mortar they would probably make a poor coke.

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STATE Name of mine or operator	Locality	Kind of coal	Coking quality	Adherence to mortar when ground	Remarks
Montana—*Continued.*					
Montana Coal & Coke Co..	Electric	Bituminous	Is coked	Medium to good.	
Montana Coal & Coke Co..	Aldridge	"	"	" "	
Western Coal & Coke Co...	Lombard	"		None	Badly crushed.
Badger Mine	Como	Lignite		"	
New Mexico					
Burns Briggs Mine	Lumbarton	Bituminous		Good	Coal bed No. 1.
St. L. R. M. & P. Co	Van Houten	"	Is coked	Excellent.	
St. L. R. M. & P. Co	Brilliant	"	"	Good.	
Madrid Mine	Madrid	Anthracite		None.	
American Fuel Co	Gallup	Subbituminous		None	Coal beds Nos. 1, 2.
Hilton Mine	Carthage	Bituminous	Is coked	Good.	
North Dakota					
Black Diamond Mine	Williston	Lignite		None.	
Washburn Lig. Coal Co...	Wilton	"		"	
Consolidated Coal Co	Lehigh	"		"	
Ohio					
Gallia Mining Co	Clarion	Bituminous		Poor	Coal bed No. 4.
Gosline & Barbour Mine...	Shawnee	"		None	M. Kittanning.
Pitts.-Belmont Coal Co....	Neffs	"	Coked in lab...	Good	Coal bed No. 8.
Superior Coal Co	Wellston	"		Poor.	
Pennsylvania					
N. Anth. Coal Co	Lopez	Semi-anthracite		"	
Phoenix Pk. Coll. Co	Minersville	Anthracite		"	
P. B. C. & E. C. Co	Ehrenfeld	Bituminous	Coked in lab...	Good.	
P. B. C. & E. C. Co	Wehrum	"	Is coked	Excellent.	
Nineveh Coal Co	Seward	"	"	Good.	
Old Colony No. 2	Ligonier	"	Coked in lab...	Excellent	Pittsburg bed.
Jamison No. 2	Hannastown	"	Is coked	Medium to good	Pittsburg bed.
Mine No. 2	Ellsworth	"	"	Excellent	Pittsburg bed.

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STATE NAME OF MINE OR OPERATOR	LOCALITY	KIND OF COAL	COKING QUALITY	ADHERENCE TO MORTAR WHEN GROUND	REMARKS
RHODE ISLAND					
Stripping	Cranston	Graphitic-anthracite		None.	
TENNESSEE					
Fork Ridge Coal & Coke Co.	Fork Ridge	Bituminous	Coked in lab...	Good.	
Southern Coal & Coke Co..	Gatliff	"	"	"	
State Mine	Petros	"	"	Excellent.	
Willow Mine No. 5	Oliver Spr.	"	Is coked	Good.	
TEXAS					
Chaffin Mine	Waldrip	"		Poor.	
Am. Lig. Briq. Co	Rockdale	Lignite		Poor	Packs.
UTAH					
North Star Mine	Vernal	Bituminous		None.	
Utah Fuel Co	Sunnyside	"	Is coked	Good.	
Utah Fuel Co	Castlegate	"	Has been coked.	Medium to good.	
[1] Pleasant Valley C. Co	Clear Creek	"		Medium.	
[1] Pleasant Valley C. Co	Winterquarters	"		Medium to good.	
Kraft's Mine	Mt. Carmel	Subbituminous		None	Packs slightly.
Old Joe Coal Hole	Kanarraville	Bituminous		"	Packs slightly.
New Harmony Coal Co	New Harmony	Semi-anthracite		"	
VIRGINIA					
Merrimac Mine	Christiansburg	"		None	
Belle Hampton	Belspring	"		Poor to medium	"Little Bed."
Belle Hampton	Belspring	"		Poor	"Big Bed."
Baby Mine	Pocahontas	Semi-bituminous	Is coked	Excellent	Coal bed No. 3.
Va. Iron, Coal & Coke Co..	Georgel	Bituminous	"	Excellent	U. Banner bed.
WASHINGTON					
Northwestern Imp. Co	Roslyn	"	Coked in lab...	Medium to good	Packs.

[1] Before the opening of the Sunnyside mine, coke was made from Castlegate coal, but this has been discontinued owing to better results having been obtained from the Sunnyside coal. Winterquarters and Clear Creek mines are on approximately the same bed as that mined at Castlegate, and it seems probable from the tests that they would produce as good coke.

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STATE NAME OF MINE OR OPERATOR	LOCALITY	KIND OF COAL	COKING QUALITY	ADHERENCE TO MORTAR WHEN GROUND	REMARKS
WEST VIRGINIA					
Elkins Coal & Coke Co....	Richard	Bituminous	Is coked.....	Excellent	U. Freeport. Packs.
Falling Rock C. C. Co....	Weir	.... "	.....	Medium	Cannel coal.
Glen Alum C. Co.....	Glen Alum.....	.... "	.....	Medium	Cannel coal.
Greenwood Coal Co.....	Lawton	.... "	Is coked.....	Excellent	Quinnimont bed.
Keeny Cr. Colliery Co.....	Winona	.. "	... "	Excellent	Sewell bed.
Star Coal & Coke Co.....	Redstar	.... "	... "	Excellent	Sewell bed.
Piney Coal & C. Co.....	Stanford	.... "	... "	Excellent	Beckley bed.
WYOMING					
Stilwell Coal Co.....	Aladdin	.... "	.....	None.	
Cambria Fuel Co.....	Cambria	.... "	Is coked.....	Medium to good.....	High in ash.
Monarch C. M. Co.....	Monarch	Subbituminous	.....	None.	
Smith Mine.....	Sheridan	..... "	.....	"	
Henn & Kahn Mine.....	Sheridan	..... "	.....	"	
Sheridan Coal Co. No. 1..	Dietz	..... "	.....	"	
Sheridan Coal Co. No. 3..	Dietz	..... "	.....	"	
Roland Mine.....	Carneyville	..... "	.....	"	
Carney Mine.....	Carneyville	..... "	.....	"	
Groat Mine.....	Carneyville	..... "	.....	"	
Evans Mine.....	Carneyville	..... "	.....	"	
Moore's Mine.....	Sheridan	..... "	.....	"	
Glen Rock C. Co.....	Glen Rock.....	..... "	.....	Poor.	
Cole Cr. Coal Co.....	Big Muddy.....	..... "	.....	"	
Cody Coal Co.....	Cody	..... "	.....	None.	
Wiley Mine.....	Cody	..... "	.....	"	
Allison Mine.....	Cody	..... "	.....	"	
East Mine of Wiley.....	Cody	..... "	.....	"	
David Dickie.....	Meeteetse	..... "	.....	"	
Horse Cr. Mine.....	Meeteetse	..... "	.....	"	
Blake Mine.....	Meeteetse	..... "	.....	"	

TABLE SHOWING RESULTS OF COKING TESTS ON 150 COALS.

STATE NAME OF MINE OR OPERATOR	LOCALITY	KIND OF COAL	COKING QUALITY	ADHERENCE TO MORTAR WHEN GROUND	REMARKS
WYOMING—*Continued.*					
Black Diamond	Meeteetse	Subbituminous		None.	
Mayfield Mine	Meeteetse	"		"	
Gebo Mine	Thermopolis	"		Poor.	
Price & Jones Mine	Thermopolis	"		"	
Point of Rocks Mine	Point of Rocks	"		None.	
U. P. Coal Co. No. 1	Rock Springs	Bituminous		Poor	Coal bed No. 1.
U. P. Coal Co. No. 5	Rock Springs	"		None	Coal bed No. 5.
U. P. Coal Co. No. 8	Rock Springs	"		None	Coal bed No. 7.
Cent. C. & C. Co	Rock Springs	"		None	Coal bed No. 7.
Sup. Min. Co. B	Superior	"		None	Coal bed No. 7.
Bethurem Mine	Carroll	Subbituminus		"	

Complete information regarding the coking qualities of all of the coals tested could not be obtained, but those left blank in the column headed " Coking quality " are supposed to be non-coking.

In studying the results tabulated above, the reader should keep in mind the fact that the samples tested were small,—two quarts or less. In the majority of cases the samples were prepared by the owner or operator, and consequently contain only the best coal mined, and probably represent only a small part of the bed.

To make the tests satisfactory, the sample should be as carefully prepared as one taken for chemical analysis, and it should be taken in the same manner, *i. e.*, by cutting a channel from roof to floor so as to include all merchantable coal. In sampling for coking tests each bench of coal should be sampled separately, and in case well-developed benches do not occur, the bed might be sampled one foot at a time, keeping each sample separate from the others and properly labeled. Each sample should be pulverized so as to pass through one-half inch mesh, and then quartered down to a convenient size for handling and transporting.

Sufficient work has not yet been done to determine the effect of moisture and ash on the adhesion of the coal, but it seems probable that they affect the result, especially when they are present in exceptionally large amounts. Until this is determined, it is better to have the samples in approximately the same conditions as regards their moisture content. If the ash is above 10 per cent., it will probably interfere with the adhesion of the fine coal, and this would indicate a poorer grade of coal than actually exists.

In conclusion the writer requests every geologist and mining engineer engaged in coal work to apply this test as occasion permits, keeping careful notes of the results, and if it fails or appears to fail, to publish the results. If the test is as successful as now anticipated, it should be used by all persons engaged in coal work, for its extreme simplicity puts it within the reach of all.

THE IRON ORES OF CANADA.

C. K. Leith.

INTRODUCTION.

I hasten to disclaim intention of attempting a comprehensive discussion of all known Canadian iron ore deposits. While I have seen many of the principal deposits in Canada and Newfoundland, and others have been examined by associates and assistants, I cannot claim to have sufficiently detailed knowledge of a considerable part of them to warrant detailed discussion. Attention will be called rather to certain general features of comparison of Canadian ores with the several types of deposits of the United States which have been more fully exploited and studied, and thus view the Canadian iron ore situation with a perspective not otherwise easily obtained. For the purposes of this discussion, the Newfoundland ores are included with the Canadian ores, because they are controlled, mined and largely used by Canadian interests. So far as is necessary, information will be drawn from the various careful descriptions of Canadian ores published by the Dominion and Provincial Geological Surveys or Mining Bureaus.

TYPES OF NORTH AMERICAN IRON ORE DEPOSITS.

The classification of iron ore deposits we shall use is partly a new one based upon recent detailed studies of the Lake Superior ores and ores of the western United States.

All metallic ores are derived ultimately from the interior of the earth, whence they are delivered by igneous eruptions near or to the surface, there to undergo various distributions and concentrations under the influence of meteoric waters and gases. The variations in composition, shape and commercial availability of an ore are controlled by variations of conditions under which the ores have reached the surface and have been distributed.

The variations are believed to have developed the following types of North American iron ore deposits:

TYPES OF NORTH AMERICAN IRON ORE DEPOSITS.

1. Magmatic Segregation type.
2. Pegmatite type.
3. Lake Superior Sedimentary type.
4. Clinton Sedimentary type.
5. Carbonate type.
6. Brown Ore type.

1. MAGMATIC SEGREGATION TYPE.

Ores brought to the outer part of the earth in molten magmas but retained in them during crystallization, with the result that the ores form part of the rock itself, just as do the feldspar and other minerals. Such are the titaniferous magnetites, containing refractory silicates, and frequently sulphur and phosphorus, in deleterious quantities. While known in enormous quantities over North America—in Canada principally along the Lower St. Lawrence River, and in the Chaffey and Matthews mines of Lower Ontario—smelting is not yet beyond the experimental stage and they are nowhere used at a profit.

2. PEGMATITE TYPE.

Ores which are carried to or near the surface in magmas and are extruded from them, in the manner of pegmatite dikes, after the remainder of the magma has been partially cooled and crystallized. They are deposited from essentially aqueous solutions mixed in varying proportions with solutions of quartz and the silicates. To this class are provisionally assigned magnetite deposits along the contacts of limestone and igneous rocks constituting the greater part of the iron ores of the western United States, and most of the magnetite ores of Vancouver and Texada Islands and elsewhere in British Columbia. The assignment of the British Columbia magnetites to this type is based on a personal comparison of them with ores in southern Utah known to be of this type, the origin of which is discussed in some detail by Mr. Harder and the writer in Bulletin No. 338 of the United States Geological Survey. The essential features of these deposits are their highly crystalline, magnetic character, their con-

tent of garnet, amphibole and other silicates, local abundance of sulphides and of apatite. The area of these deposits at the surface varies up to about 0.2 of a square mile. They are easily located by their outcrops or by the fragments strewn down the slopes, but it is not so easy to determine the shape and extent of the deposits when found because of their extremely irregular association with wall rock. It is not safe to assume that they extend a foot beyond the zone of direct observation. Their vertical dimensions and shape and their mineralogical composition at depth are relatively unknown. Mining operations in the west on this class of deposits have not been extensive enough to determine these facts, such deposits having been mined in but few localities, principally at Texada Island, at Fierro, New Mexico, and in the Monterey and Durango deposits of Mexico. In the United States and Mexico certain similar deposits, but not all, have been found to take on sulphur and garnet with depth.

A small amount of ore has been mined from Texada Island. The better ore averages about 55 per cent. iron content, and from this down. Much of it is below Bessemer limit in phosphorus, and sulphur is in amounts requiring roasting. Garnet and amphibole are both abundant, locally requiring hand sorting. Silica varies, inversely as the iron, up to about 11 per cent. All of the ore contains a small amount of copper, locally as much as 4 per cent. The shapes of the deposits are extremely irregular. Seldom do the widths exceed 100 feet. In depth they are best shown by a tunnel 300 feet below the surface which discloses ore with essentially the same width and composition as at the surface.

The ores on the west coast of Vancouver Island have had only a little development work done on them. They likewise vary widely in iron content; phosphorus is low, sulphur is usually high, silica varies up to about 26 per cent.

Making due allowances for lack of development and possible shallowness and change of character with depth, it is still certain that there is a considerable tonnage available in British Columbia, which will be used when West Coast demands warrant the estab-

lishment of a local steel industry, instead of the importation of finished products from the east. There are indications that this time may not be far distant. While suffering somewhat from their composition, they are easily and cheaply mined, and being located directly upon the coast, will have the cheapest transportation. So far as the ores have thus far been used, it has been in Washington, and the extremely rapid development of the northwestern United States suggests that their further immediate use will be in Washington, notwithstanding duty, at least until such time as sufficiently large ore reserves in this part of the United States becomes developed or until the population of British Columbia warrants a steel industry of its own.

To the pegmatite type are provisionally assigned the ores of the Attikokan and Hutton districts, of Ontario, where the magnetites have the mineralogical and chemical constituents of this class and show such intimate relations with greenstone as to suggest a direct derivation from it. They lack the bedded structures characteristic of ores of class (3) to be described, though in the Hutton district the bedded iron formation rocks are also present. The extremely irregular association of the ore with greenstone makes it difficult to outline the deposit even a few feet in advance of exploration. The Attikokan deposits are high in sulphur, 2 to 5 per cent., requiring roasting. At Hutton the sulphur is low so far as explorations yet go, and phosphorus runs about .1 per cent.

To this class of ores also may belong at least a part of the magnetites in the pre-Cambrian Grenville series of New Jersey,[1] some of the magnetites of the Adirondacks of New York,[2] some of the magnetites in the Grenville series of southeastern Ontario,[3] and the magnetites of Cornwall, Pa.,[4] and Cranberry, N. C.[5]

[1] Spencer, A. C., "Genesis of the Magnetite Deposits in Sussex County, N. J." *Min. Mag.*, Vol. 10, 1904, pp. 377–381.

[2] Kemp, J. F., "The Geology of the Magnetites Near Port Henry, N. Y., and Especially Those of Mineville," *Trans. Am. Inst. Min. Engs.*, Vol. 27, 1898, pp. 146–203.

[3] Brock, R. W., discussion of this paper, Proc. Can. Min. Inst., May *Bulletin*, 1908.

[4] Kemp, J. F., "The Ore Deposits of the United States and Canada," New York, 3d ed., 1900, pp. 175–179.

[5] Keith, Arthur, "Iron Ore Deposits of the Cranberry District, North Carolina-Tennessee," Bull. U. S. Geol. Survey No. 213, 1902, pp. 243–246.

These deposits have essential features in common and mineralogical and chemical similarities to the western ores of this class. It may be that part of the Ontario Grenville ores belong also with the following class (3), suggested not only by their characteristics, but by Mr. Miller's recent correlation of certain associated rocks with the Keewatin series of the Lake Superior region, which contains ores belonging to both classes (2) and (3).

The Grenville ores of lower Ontario are interbanded lenses of magnetite, gneisses and amphibolites, closely associated with, and partly in direct contact with, crystalline limestones of the same series. The ores vary from lean unworkable magnetite gneiss, carrying a small percentage of magnetite ribs as compared with gneissic ribs, to deposits of nearly pure magnetite. The iron formation bands are lens shaped and discontinuous. Their greatest width is probably less than 150 feet and usually under 50 feet, and their greatest length perhaps 1,500 feet. They have been mined to a depth of 350 feet, but most of the workings are less than 100 feet. The better grade ores average much the same in iron as the better grade western magnetites of this class, that is about 55 per cent., and from this down. Phosphorus is usually below the Bessemer limit, adding much to the availability of the ores. Sulphur is usually too high to allow the ore to be used without roasting, seldom running less than .05 per cent., though by hand cobbing the sulphur content may be kept down somewhere near this limit. Concentration of certain of the leaner grade ores is likely to be commercially feasible in the future, though this is yet a mooted question, especially with reference to the satisfactory elimination of sulphur. In a few places titanium is present.

Hematite has been mined at Wallbridge, Dalhousie and McNab in eastern Ontario in similar geological relationships. According to Willmott,[1] there is reason for believing that they are oxidized portions of iron pyrites bodies lying below.

A deposit of magnetite not far from Bathurst, New Brunswick,

[1] Willmott, A. B., "The Iron Ores of Ontario," *Jour. Canadian Min. Inst.*, Vol. XI., 1908.

seems from its available description[1] to belong with this class of pegmatite ores, but I do not have sufficient information to discuss it.

3. LAKE SUPERIOR SEDIMENTARY TYPE.

Ores brought to the surface by igneous rocks and contributed either directly by hot magmatic waters to the ocean or later brought by surface waters under weathering to the ocean or other body of water or by both; from the ocean deposited as a chemical sediment in conformable succession of sedimentary rocks; and, still later, under conditions of weathering, locally enriched to ore by percolating surface waters. To this class belong most of the producing iron ores of the Lake Superior region, those of the Michipicoten district of Canada, and most of the non-producing banded iron formation belts of Ontario and eastern Canada. The Lake Superior ores constitute the world's largest reserve of high grade hematite, more or less hydrated, much of it of Bessemer grade, and little of it high either in phosphorus or sulphur.

The ores of this class differ in origin from those of the preceding classes in that the iron, instead of being directly deposited near igneous rocks as ore, is distributed by aqueous sedimentation and deposited with a large amount of interlayered silica in banded "iron formation," containing about 25 per cent. of iron, —too poor to be used directly as ore, and requiring that the silica be locally taken out before it is of value. This ore may or may not show close areal association with the parent igneous rocks. It is obvious that gradation phases are to be expected between groups (2) and (3), and that many ore deposits can with difficulty be assigned definitely to one or to the other.

It has long been known that the Lake Superior ores were concentrates in certain sedimentary iron formations. It was believed that these sedimentary iron formations were derived from the weathering of basic shores containing much basic igneous rock, usually called "greenstone." As a result of further study it has been found necessary to conclude that the iron formations

[1] Hardman, John E., "A New Iron Ore Field in Eastern Canada," *Jour. Canadian Mining Institute*, Vol. XI., 1908.

have not only been derived from greenstone by weathering, but have actually been contributed by the greenstones directly to the water in magmatic solution and that there are all intermediate stages between the two processes. It begins also to appear that the iron, copper, nickel and silver ores of the Lake Superior and Lake Huron districts are related in a great metallographic province in which the characteristics and distribution of the different ores are initially controlled by igneous rocks.

This conclusion has an essential bearing on exploration, for if the iron is specifically related to certain greenstones, just as the Sudbury ores are to the norite, then it follows that its distribution may be somewhat freakish, as it is in any ores related to igneous activity, as for instance, the gold ores of the west, and that it cannot be concluded from similarity in succession or structure that iron ores should necessarily be found in a distant district, though the redistribution as sedimentary rocks which the iron ores alone have undergone has greatly increased their area and the chances of finding them.

As first deposited the iron formation consisted essentially of iron carbonate or ferrous silicate (greenalite) with some ferric oxide, all minutely interlayered with chert, forming the ferruginous chert. When these were exposed to weathering, the ferrous compounds, the siderite and greenalite, oxidized to hematite and limonite, essentially in situ, although some of it was simultaneously carried and redeposited. The result was ferruginous chert or jasper averaging less than 30 per cent. of iron. The concentration of the iron to 50 per cent. and over has been accomplished essentially by the leaching of silica bands from the ferruginous chert and jasper. Infiltration of iron has been on a smaller and more variable scale. The leaching of the silica develops pore space, and allows the iron layers to slump, thereby enriching the formation sufficiently to constitute an ore.

It has been found, recently, that during this leaching of silica the character of the iron bands has not essentially changed and therefore that the nature of the ore deposits is determined largely by the character of the bands in the chert. The phosphorus is in the iron bands, rather than in the chert, and consequently leaching

of the chert tends to raise the percentage of phosphorus in the ore, but there has been also later introduction of phosphorus, making the phosphorus content of the ore considerably higher than that of the parent rock.

For flat-lying formation such as the Mesabi from 4 to 8 per cent. of the surface of the formation and less than 2 per cent. of the volume of the part of the formation lying immediately below this exposed surface have been altered to ore. For steep dipping formations like the Gogebic, about the same percentage of the volume has been altered to a depth of 2,000 feet.

I have discussed the Lake Superior ores only so far as necessary to bring out certain essential features of this class of ores in Canada and their bearing upon availability. There are many iron formation belts of this class, but they have been found to have undergone local enrichments to important ore deposits only in the Michipicoten district, and to some extent in the Animikie district.

In the Michipicoten district the ores are principally non-Bessemer and in portions of the deposits high in sulphur. Their occurrence beneath the peculiar Boyer Lake basin with walls of chert, tuff and carbonate, is well described by Coleman and Willmott.[1]

In the Animikie district the iron formation is an eastward continuation of the Mesabi iron formation, but it is less than 200 feet thick, as compared with 700 to 1,000 feet in the Mesabi, and has undergone enrichment only in thin layers interbedded with cherts and along a few fault planes. The thickness of the ore beds that may be mined will depend on how low a grade can be used and the success of hand sorting in keeping the ore up to this grade. Under any conditions much rock must be handled. On the other hand, the ores have great horizontal extent, are near the surface, are red hematite, low in phosphorus, with low sulphur, and practically on the shore of Lake Superior, justifying the hope that they may be used.

Two significant questions may be asked in connection with

[1] Coleman, A. P., and Willmott, A. B., "The Michipicoten Iron Region," 11th Report of the Ontario Bureau of Mines, 1902, pp. 168–169.

the lean iron formation of the Lake Superior type so widely distributed in Ontario and elsewhere in Canada: (1) Is their apparent lack of second concentration a real one; and (2) if so, what has caused it? On the assumption that the apparent lack of concentration is a real one, Van Hise has suggested that perhaps a part of the enriched portions have been removed by deep glacial erosion. Another alternative is that the structural conditions have not favored abundant flow of surface waters necessary for the leaching of the silica. A third possibility, now more favored, is that the original texture of the iron formations or proportions of the original constituents have been somewhat different from those of the Lake Superior region, and that they have not allowed access to the waters necessary to leach the silica. The formations are principally Keewatin and in general are more dense, crystalline and magnetic than the Huronian iron formations of the Lake Superior region. Some of these differences are doubtless due to secondary alterations, but it is not easy to account for all of the differences in this way. Another possible reason for deficiency of ore in the Ontario iron formations is that their yet known area is so small as compared with that in the Lake Superior region that even if the same percentage of the formation were concentrated to ore, the total amount of ore to be discovered would not be large. The Keewatin formations of the Lake Superior region occupy only about 9 per cent. of the area of all the iron formations and have produced only 7 per cent. of all the ore mined to date.[1] There may be unfavorable significance, therefore, as noted by Willmott, in the fact that the Canadian formations thus far discovered are largely Keewatin.

All these explanations and possibly others may apply. On the other hand, much more exploration is necessary to show that there really has not been concentration of large ore deposits in the known Canadian iron formations. The fact is again cited, that, in the producing Lake Superior districts, the proportion of ore, even under most favorable conditions, constitutes less than 8 per cent. of the surface of the iron formation and usually

[1] Willmott, A. B., "The Iron Ores of Ontario," *Jour. Canadian Min. Inst.*, Vol. XI., 1908.

much less, and in volume it constitutes less than 2 per cent. Only rarely have the ores been discovered at the surface. Underground exploration through drift and rock has been necessary. In but few localities in Canada has there been adequate search for such localized concentrations within the iron formations. This fact is sometimes lost sight of because of marked tendency to use the term "iron ore" for the banded, unconcentrated "iron formation," and to speak of such formation as "lean, banded ore." In the Lake Superior region "iron formations" and "iron ores" are discriminated. It is not impossible that mechanical concentration of the iron formation may result in the production of ore, but it is unnecessary to argue the commercial advantage of finding some part of the iron formation in which the concentrating has already been done.

4. CLINTON SEDIMENTARY TYPE.

Sedimentary ores derived from weathering of the land areas in which the iron is either disseminated in igneous rocks or has undergone some of the concentrations outlined in (1), (2) and (3). To this class belong the "flax seed" ores of the Clinton and other beds of the Appalachians and Wisconsin, the ores of the Torbrook and Nictaux areas of Nova Scotia, and those of Belle Isle in Newfoundland. They have now been discovered in Missouri.[1] They are believed to differ in origin essentially from those of the preceding classes in that they are deposited as iron oxide rather than as ferrous silicates, and that they have undergone no further concentration, being mined essentially in the condition in which they were deposited. There has long been some doubt as to whether or not these ores might not represent two concentrations, but recent work in the southeastern United States by Eckel and others,[2] for the U. S. Geological Survey, and our own observations in Wisconsin, seem to show one concentration.

[1] Buckley, E. R., state geologist of Missouri. Personal communication.

[2] Eckel, E. C., "The Clinton or Red Ores of northern Alabama," Bull. U. S. Geol. Survey No. 285, 1906, pp. 172–179. Burchard, E. F., "Clinton Ores of Birmingham District, Ala.," Bull. U. S. Geol. Survey No. 315, 1907, Pt. I., pp. 130–151.

On Belle Isle the ores are beds dipping about 9° to the northwest, in two main seams. The lower or Dominion seam averages about 10 feet in thickness, though variable, and extends across the island for about three miles along the strike and down the dip for perhaps half a mile, covering an area of 818 acres, although not productive for this entire area. The upper seam occupies an area about one by one third mile (240 acres) averaging seven feet in thickness and is not all productive. The mining has been largely open pit, but is becoming more largely underground as the ore is followed down the dip. They are now being followed under the ocean by drifting. Much of the upper bed averages about 52 per cent. in iron and the lower bed about 50 per cent. Recent shipments are reported to be under 50 per cent. Phosphorus averages 1 per cent. The ores are adapted to basic Bessemer or open hearth treatment and for the former receive a bonus for high phosphorus from some European consumers.

In the Torbrook and Nictaux areas the ores are of similar kind, but the beds differ from those of Belle Isle in being thinner and inclined, requiring deep mining and handling of waste rock.

Ores of this kind occupying a definite stratigraphic position, are easily explored for, and so far as their future in Canada is concerned, they have already been pretty well discounted.

5. CARBONATE TYPE.

Carbonate ores, derived from weathering of rocks, transported and deposited with organic reducing material in bogs; now found in thin beds usually associated with coal seams or carbonaceous shales. These have been extensively mined in the coal-bearing and adjacent areas of the eastern United States, but not in Canada. Their present production in the United States is almost nil. Where exposed to weathering they alter to limonite or brown ores, considered under the following heading. Iron carbonates constitute minor phases of class 3.

6. BROWN ORE TYPE.

Brown or hydrated ores, developed either from the weathering of iron carbonates mentioned in the preceding heading, or of

limestones containing carbonate or other iron minerals, or by replacement of limestone, or by oxidation of pyrites, or by deposition in, or leaching of glacial drift, or by some combination of them. The few limonites in class 3 are not here included. The brown ores are left by the weathering essentially in situ. Being essentially residual products of weathering, they are characteristically mixed with other residual products of weathering, particularly clay. To use these ores it is necessary to wash out the other residual products, a process which nature neglected to attend to. The ores are characteristically hydrous and high in phosphorus, but when washed are found highly suitable for open hearth furnace practice.

The bog ores of Quebec presumably belong to this class.

Related to classes 5 and 6 are the Londonderry ores, of Nova Scotia, consisting of carbonates of iron, calcium and magnesium, showing more or less alteration of limonite, in irregular vein-like masses in slate and quartzite. These ores are low grade, fairly high in phosphorus, manganese and silica, and are extremely irregular in their shape and distribution. Their origin is in doubt.

7. MAGNETIC SANDS.

Magnetic sands are developed from the erosion of classes 1, 2 and 3. As exposed along the lower St. Lawrence river they are probably principally from classes 1 and 2 and are usually high in titanium. They form beds from one half inch to two feet in thickness with wide extent. Their availability is still in doubt.

COMMERCIAL IMPORTANCE OF THE SEVERAL CLASSES OF ORES.

The proportions of the several classes of ores mined in the United States, Canada, and Newfoundland, for 1906, appears in the subjoined table. Where the origin of the deposits is in doubt, the classification of their production is in doubt, but the production from such types is too small to introduce any essential error into the figures given.

PRODUCTION OF DIFFERENT CLASSES OF IRON ORES IN 1906 IN TERMS OF PERCENTAGE OF TOTAL PRODUCTION.

		U. S.	Canada and Newfoundland.
Class 1.	Magmatic segregation (magnetite)	.00	.0
Class 2.	Pegmatite type (magnetite)	5.2	12.29
Class 3.	Lake Superior sedimentary type (hematite)	80.	
Class 4.	Clinton sedimentary type (hematite)	8.	
Class 5.	Carbonate type	1.	8.51
Class 6.	Brown ore type (limonite)	5.8	

The dominance of class 3 (Lake Superior ores) in the United States production shows how desirable it is to have the ores go through nature's concentrating mill. These are the only ores which have undergone second local enrichments. That the less desirable grades of ore should compete at all with the Lake Superior grades is due largely to lower freights between ores and furnaces, between fuel and fluxing materials and furnaces, and between furnaces and consuming centers. Iron ores differ from most other metallic ores in that their great bulk, as compared with their value, requires cheap transportation, which operates to develop certain low grade deposits well situated in this regard at the expense of better grade ores.

Turning to the Canadian production, it appears from the table that the proportions of different classes of ores mined are quite different from those of the United States and that a far larger proportion of Canadian ores are being drawn from less desirable classes. The class which produces 86 per cent of the United States production produces only 12.29 per cent of the Canadian production.

It appears, therefore, that in order to compete with the United States on equal terms so far as grades of ore are concerned, Canadian ores of the Lake Superior type should be more largely developed. The proportions and amounts of ores of the Lake Superior type now mined in Canada are not far different from those of the United States fifty years ago, before the advent of high grade Lake Superior ores had revolutionized the industry. It is not meant to imply that Canada is fifty years behind the times in this regard, but rather to call attention to its latent possibilities for the future and probable direction of development.

It does not follow that the production of ores other than of the Lake Superior class may not also increase, because of low freights or artificial aids in the way of tariff or for other reasons.

Similar conclusions seem to follow from a consideration of ore reserves. I fully realize the uncertain nature of estimates of undeveloped deposits and the wide variety of figures that may be gotten by conscientious observers with different points of view or different methods, but certain essential features of our knowledge concerning reserves are fairly well established and a brief summary of them will help to bring the Canadian iron ore situation somewhat more definitely before us.

The titaniferous ores of class 1 not being mined, there is no point in attempting estimates, indeed, they are not sufficiently well developed to warrant estimates.

The British Columbia magnetite of class 2 has been subject to a wide range of estimates depending upon how low a grade of ore is included, upon the depth arbitrarily assigned, and upon the extent to which isolated portions of deposits are assumed to be continuous. Using only the extents and depths known, the tonnage of ore of commercial grade may be measured in a few tens of millions.

The difficulty of estimating the Attikokan and Hutton ore of class 2 is due to their mixture of greenstone, making it impossible to predict in advance of exploration the extent of the deposits. In both districts the explorations show at least several millions of tons.

For the Lake Superior ores of type 3 in the Michipicoten district Coleman and Willmott have estimated a reserve of possibly two millions of tons. Some of this reserve is of doubtful value because of high content of sulphur. In the Animikie district the tonnage is problematic because of conditions described for that district, but at best the ore to be recovered is not in large amount. The reports of hundreds of millions of tons of ore of the Lake Superior type in various parts of Canada so frequently seen in print are without foundation except as they cover commercially non-available lean iron formation, rather than ores. Even under the best conditions but a small

fraction of the iron of these formations is likely to be ore of commercial grade.

The Grenville ores of lower Ontario show wide variations of estimates depending upon the factors chosen. The known dimensions of commercial grades indicate not more than a very few millions of tons.

I have little knowledge on which to base an estimate of the Londonderry carbonate and limonite ores, but no one claims these deposits to be of the first magnitude.

The ores of the Clinton type of Newfoundland (class 3) are sharply delimited on Belle Isle and the reserve tonnage carefully estimated. The doubtful feature is the amount of ore below present commercial grade and the amount of available ore in the beds known to extend under the ocean. The ore on the islands alone has been estimated at about thirty milions of tons. The amount available beneath the ocean is now being shown by drifting to be large and may be several times this figure. The reserve is large because the ores make up the entire beds, rather than concentrations within the beds.

The similar beds of Nova Scotia are so thin that only a part of them can be counted as commercially available. Commercial estimates have been four million tons to level of 700 feet on the principal group of properties.

It appears in general, then, that the proportion of reserve of Canadian ore of the Lake Superior type to the total reserves is probably not greater than the proportion of their annual production to total annual production. It is not held for a moment that the tonnage of all of these classes to be ultimately developed may not be considerably larger than here indicated, but whether they be increased or decreased, it will be because of introducing factors of depth or grade partly common to all of them. This is not likely to change their proportion sufficiently to obscure the fact that the most desirable ores of the Lake Superior type of class 3 are not yet developed in large enough tonnage to insure the future competition of Canadian iron ores with those of the United States on an equal basis. In competition with the great reserves of high grade ores of the Lake Superior region

the principal Canadian reserves thus far developed suffer handicaps in grade and in content of deleterious constituents. These handicaps are and will be overcome to a certain extent by bounties or locally by favorable conditions of transportation, but that they exist is shown by the extremely vigorous search for iron ore of the Lake Superior type by Canadian mining interests, by the importation of Lake Superior ore to the amount of four-fifths of the ore used in Ontario, and by the recent increase in proportion of ore imported to home production, due to Canadian demand for finished products having gone ahead of the production from Canadian ores.

That ores of the Lake Superior type are in larger quantities in Canada than are now known seems likely, in view of the position of the Lake Superior region as a mere southern fringe of the great Canadian area of the pre-Cambrian rocks. Their discovery will require closer search than has been previously made in any but isolated localities, for it is not only necessary to find the iron formation, but to find the small fraction of this formation which may have been secondarily concentrated. The vast area, the difficulties of travel, and the drift covering, requiring drilling, all combine to make the task a difficult one and partly explain why the search is not farther advanced. On the other hand, exploration may never develop abundant ores of the Lake Superior type for geological reasons discussed under class 3.

SOME PROBLEMS OF THE FORMATION OF COAL.[1]

DAVID WHITE.

INTRODUCTION.

The question of the formation of coal is not merely that of the genesis of a certain coal, but of many coals of different kinds. To attempt to discuss all the matters, geological, biological and chemical, of coal formation—even confining the treatment to those on which there is still lack of agreement—would involve a prolonged dissertation. In the following paragraphs a few only of these matters will be briefly considered solely from the standpoint of the geologist and paleontologist, the motive being to point out to geologists certain needs for further field observation on their part; to call their attention to progress recently made in the solution of some of the problems; and to bring forward observations or opinions which may be timely and possibly helpful to the better understanding of the process as a whole.

The sedimentary nature of our stratified coals is not now seriously questioned by any person possessed of geological training. It is no longer necessary to argue that it is a stratified carbonaceous deposit of first-hand organic débris in which the vegetal elements greatly predominate, at least optically.

The factors of most importance in the genesis of coals of all kinds relate chiefly to (*a*) the conditions of growth and accumulation of the organic matter; (*b*) the kinds of organisms contributing directly or indirectly to the mass or accumulation and the relative proportions of each; (*c*) the conditions, and duration of the initial process of organic decomposition or putrefaction; and (*d*) the nature and energy of the dynamic forces bringing about in varying degrees the subsequent alteration of the organic residues.

The factors of these four classes combine not only in infinite

[1] Published by permission of the Director of the U. S. Geological Survey.

complexities, but also in constantly changing activities or values, the products of their combined influences, even throughout a single bed at a given point, being never exactly the same. Therefore it is not remarkable that there should be absolute and complete intergradation from extreme to extreme, or that no naturally separated groups can be found by which to illustrate the distinctions in a coal classification. The dividing lines of the latter must accordingly be arbitrarily drawn. That classification will ultimately win most general acceptance and satisfaction in which the groups are perspectively formed with due reference to the optical and physical characters of the coals as well as to their chemical and commercial qualities. Incidentally such a classification will conform in a general way to the genetic relations of the coals.

CONDITIONS OF VEGETAL GROWTH AND ACCUMULATION.

So far, at least, as concerns the coals of the Upper Carboniferous (Pennsylvanian) it is generally agreed that the plant types grew in greatest profusion and often of large size under the favoring conditions of a humid and extraordinarily equable, though not necessarily a tropical or even subtropical climate. In the Appalachian and Interior Carboniferous coal fields of this continent the vegetation clothed a peneplain which for a long time suffered intermittent subsidence. In general, even in the later periods of less equable climate, it is probably safe to assume that plant growth was most luxuriant in those periods and regions marked by the greatest deposition of coal.

The question as to whether the coal-forming vegetation grew in the place where it now lies, or whether it was brought from some other habitat, is still, after more than a century of discussion, a matter of dispute. Profiting by the unrivalled opportunities offered by the structure and exploitation methods of the coal fields of central France, Fayol[1] and several other geologists and paleontologists appear to have clearly established the validity of the the transportation (allochthonous) theory in the deposition of the coal in deltas in some of the fresh water basins

[1] *Bull. Soc. ind. min.*, Sept. 16, 1880.

like that of Commentry. The application of the same hypothesis to other coalfields of the world has been most ably championed by de Lapparent.[1] Yet it must be noted that even in the interpretation of the conditions prevailing in these typical delta or lacustrine deposits there is difference of opinion as to the precise conditions of growth and the amount of transportation. M. Grand'Eury,[2] who, more than any other living geologist or paleontologist, has contributed invaluable data bearing on this question, and whose observations on the habits of growth and the relations of the plants to old soils have proved most illuminating, is of the opinion that, in general, the land plants which enter so largely into the composition of our ordinary "bituminous" coals owe their present position and attitude to water movement, though the swamp conditions of their habitat necessitated no distant transfer nor marked orogenic oscillation.

On the whole, however, it seems to the writer that the advocates of the peat-bog or peat-swamp theory have, in most cases, the best of the question, at least so far as it concerns Paleozoic coals. The study of the development of roots in higher layers of a deepening root stratum; the tendency to nodal development in roots and trunks, with the growth of roots from successively higher nodes; the anatomical characters of some of the vegetal types; and the close examination of the rock itself go to show, as Grand'Eury has so well demonstrated, that the Stigmaria clays which in the great majority of cases underlie the Carboniferous coals are unquestionably old soils. The writer's limited observations of the substratums of Mesozoic and Tertiary coals indicate in most cases the presence of old soils beneath the latter also.

Potonié, at present, perhaps, the most radical supporter of the growth-in-place (autochthonous) theory, forcibly reiterates the argument that the size of the fragile plant segments and the state of preservation of the delicate fern laminæ, as if spread out on the herbarium sheet, in the roof of the coal bed, are proof of growth essentially in place. He urges[3] that plants in transport

[1] "L' Origine de la Houill," *Rev. quest. scientif.*, July, 1892.
[2] *Comptes Rendus*, April 21, 1904, p. 740; February 22, 1904, p. 460; June 5, 1900; July 16, 1900.
[3] *Naturwiss. Wochenschr.*, February 19, 1899, p. 81.

are quickly twisted, rumpled, torn and disintegrated in the moving waters of lacustrine or fluviatile currents so that they will seldom or never reach bottom in recognizable condition. Transported (allochthonous) plant remains, such as may at the present time be observed in littoral regions and in deeper dredgings reveal, he insists, nothing but comminuted, water-worn, and somewhat macerated particles, more or less distinctly graded in size like other sediments. Such macerated and ground-up plant material, which he terms " Häcksel," is not rare in our Carboniferous sandstones and current-bedded shales.

It is agreed among paleobotanists that the vegetal matter forming coal has been laid down in water. Some of this coal-forming débris has evidently been more or less rearranged and evenly spread out in water. The study of the topography and mutual relations of certain of our patchy (littoral) coals—the Sharon coal of western Pennsylvania and northern Ohio, for example—indicate deposition in quiet pools, behind bars or reefs, or in estuaries, deltas, etc.[1] In most coals the plant accumulation overlies a submerged old soil and appears to have attended subsidence, their thickness and characters being often largely influenced by the conditions of the latter.[2] Given a too rapid subsidence, the coal-forming vegetation is not able to maintain its exclusive position and monopoly in the sedimentary accumulation, but is obliged to retreat, the resulting impairment or interruption of the carbonaceous deposition being marked often by destruction of the more slowly contributed organic matter or the invasion of mineral sediments which are stratified. In the Appalachian trough the coals are generally capped by clays or sands, usually mingled, and often containing large plant fragments, though rarely a marine limestone lies directly on the coal. It is interesting to note that in the Eastern Interior coalfield of Illinois and Indiana the more widely distributed as well as most important coals are

[1] The presence of important beds of coal in a purely fluviatile series is not yet satisfactorily proven, though there is no doubt as to coal formation under lacustrine conditions.

[2] Proof of subsidence is so clear in the coals of the larger fields or marine basins that presence of large coal areas in any region is, in itself, evidence of extensive submergence of base-levelled land.

generally capped by sapropelic[1] deposits containing marine shells, while recognizable ferns are relatively rare.

The rare occurrence of coals without underclays or any evidence of old soils; with abrupt clay partings containing marine shells or wedging out, perhaps, at one side so as to permit the union of two benches; and the presence of marine invertebrates or even of limestone immediately over the coal, which may be observed in some instances, are difficult of explanation without the aid of a modified transportation theory. Neither the autochthonous nor the allochthonous theory seems by itself to offer a completely satisfactory explanation for the great extent, relative regularity in thickness and character over great distances, and the uniformity of structure, including the continuity and thickness of benches and partings, exhibited so clearly by the great Pittsburg coal bed in a multitude of sections in Pennsylvania, Ohio and West Virginia. Possibly the difficulty lies chiefly in our inability to conceive that present processes could have operated in the magnitude required by Paleozoic facts. It is probable that aid in this explanation may come from a more thorough study of the vegetal accumulations forming at the present day under coast-level swamp, salt marsh, estuarine, or even more distinctly marine conditions.

The homologues of coal formation seem to lie with the coastal bogs, marshes or lagoons and estuaries; with the low moors, and with the deltas; but seldom if ever with the high moors.

VARIETIES OF ORGANISMS AND KINDS OF COAL.

Renewed interest in the subject of the influence of the contributary organism in determining the character of the coal, and high appreciation of the importance of this factor in the genesis of various coals have been stimulated by the brilliant results achieved by the late Professor B. Renault, of Paris, and his associate, Professor C. E. Bertrand, of Lille. To these authors is largely due not only a natural and satisfactory explanation of the initial process of coalification, but also a very important knowledge of

[1] "Sapropelic" and "sapropel" will be defined in the discussion of contributing organic matter (p. 298).

the mechanical constitution and origin of certain coals and bituminous rocks.

It has long been known that the Paleozoic cannels and splints are characterized by great numbers of spores and pollen grains, and a relative scarcity of woody matter, such as natural charcoal or "mother of coal." Considerable attention also has been given to the kinds of woods entering into the coals of various epochs, and, from the chemical and mineralogical standpoint, to the fossil resins.

It is impossible here to summarize in more than the meagerest form the coal work done by the above named French botanists.[1] Following the lines suggested by von Gümbel,[2] they demonstrated that the bogheads, including the Torbanite and Australian Kerosene shales, are preponderantly composed of the residues, generally remarkably well preserved, of the thalli of various gelosic (gelatinous) micro-algæ. In some cases these comprise nearly the entire rock mass, counting over 250,000 per cubic centimeter. Similar micro-algæ are present in many of the richer bituminous shales, especially those exploited for illuminating gas. Evidence of the presence of zoological elements, including microscopical types, is usually observed, particularly in the deposits of Cretaceous or Tertiary age.

The bogheads grade into a fuel containing numerous spores and pollen grains mingled with the algal thalli. This Renault called "Cannel-boghead." The latter in turn is connected by intermediate phases with the "boghead-cannel," in which the spores, etc., predominate and the algæ are rare and often difficult of detection. In the ordinary cannel, as described by Renault, the presence of the algæ is often indeterminable.

The above-mentioned coals are largely similar in aspect, and are characterized by yielding volatile hydrocarbons of very high value as illuminants, both the value and volume of the gases being in general greatest when the algal residues are in greatest

[1] B. Renault, "Sur quelques microorganismes de combustibles fossils," St. Etienne, 1900. C. E. Bertrand, "Les Charbons humiques et les Charbons de Purins," *Trav. et Mém. Univ. Lille,* Vol. VI., mem. 21, 1888.

[2] "Beiträge z. Kenntn. d. Texturverhältnisse d. Mineral.-Kohlen," München, 1883.

numbers. Since the amount of hydrogen and carbon are much greater than is readily explained by the fossilization and reduction of the substance of the gelatinous algæ, Renault concludes, apparently with very good reason, that the algal residues exert an attractive influence on certain bituminous compounds and are consequently enriched. The writer is disposed to regard the algæ as impregnated with bitumen or similar hydrocarbons largely derived from the decomposition of the associated faunal elements, or, perhaps, in part from the putrefaction of great numbers of the original algæ. Reference will again be made to this subject in connection with the putrefactive process.

Observing that the alga coals studied by Renault and Bertrand yielded petrolic oils as well as highly illuminative gases on distillation, their richness seeming to depend on the algal proportion, the writer was prompted to examine several well-recognized oil rocks with a view to detecting the presence of analogous algæ as constituting a probable original source of the volatile hydrocarbons. Micro-algæ were found to form a considerable part of the oil shale reported to have come from the Permian of Brazil and the Eocene of Arkansas. Portions of the "oil rock" at Plattville, Wis., were found to consist mostly of what appear to be flattened, gelatinous, unicellular algæ, probably allied to the Protococcales. The composition of this oil rock from the Trenton offered, in the writer's judgment,[1] a satisfactory explanation of the genesis of the petroleum and gas in our Paleozoic formations. While the Diatomaceæ may, in some instances, have been the source of the Tertiary and some Cretaceous oils and gases the conclusion that those in the older sedimentary rocks are probably derived by pressure-distillation from gelatinous micro-algæ appears, to the writer, to be well founded.

The discovery of hydrocarbon-bearing strata composed largely of such organisms in rocks as old as the Ordovician strongly suggests an algal origin for the graphites interbedded in still older metamorphic sediments of the Laurentian or Algonkian. The question of the part played by algæ in the genesis of petroleums

[1] *Science*, May 25, 1906, p. 864. The algæ comprise over 80 per cent. of portions of the "oil rock" from Plattville.

was meanwhile being considered independently by Potonié, whose conclusions, appearing almost simultaneously, are substantially the same. This able German paleobotanist, who now has devoted much research and discussion[1] to the subject, applies the term "Sapropel" to the accumulating residuum of the gelatinous or fatty algæ mingled with more or less animal matter partially decomposed or putrefied in stagnant or quiet water. The carbonaceous rock formed dominantly of this substance he terms "Sapranthrakon" if Paleozoic, or "Saprodil" if Tertiary in age. Consistently a rock, not necessarily a fuel, in which sapropelic matter forms a considerable part is a "Sapropelite." Sapropel he calls the "mother rock" of petroleum.

As designating shales or sandstones characterized by the presence of such residues, and therefore bituminous, strictly speaking, the term sapropelic is preferable as well as appropriate, since, as will be shown later, the word "bituminous" is, in a sense, ordinarily misapplied in coal terminology. A pure alga-coal—boghead—or cannel-boghead, is a typical Sapranthrakon or Saprodil, Sapropelic matter, whether comprising coals or merely included in other sediments, is, in general, characterized by its more distinctly bituminous composition, being relatively rich in hydrogen and low in oxygen. Its marked contrast in chemical composition with the so-called bituminous coals will be noted in connection with the discussion of the putrefactive process.

The sapropelic (gelosic) or algal coals are macroscopically distinguished by their conchoidal fracture; a rather dull black surface, which in the purer samples have a satiny luster; a greasy or waxy abrasion when scratched by some hard instrument; a more or less distinctly brownish tint when broken in thin edges, and often a golden yellow color in thin sections. Usually the coal is massive and unlaminated. From a boghead or relatively pure alga rock, such as that just described, the coal may grade into a sapropelic limestone, or sapropelic shale, etc.

Sapropelic deposits in the form of an alga-cannel may occur in any part of a bituminous coal bed. Under these circumstances

[1] "Entstehung d. Steinkohle u. verwandter Bildungen einschliesslich d. Petroleums," Berlin, 1905.

the alga-cannels or bogheads are horizontally continuous with the " bituminous " coals with which they intergrade.

Alga coals and incipient cannels are not rare in the younger and less altered lignites. Alga (bituminous) shales of high hydrocarbon contents are known in beds, probably Miocene, in Brazil. Intergrading phases may occur in coals of any age, though often passing unnoticed, especially in the less mature fuels. In fact layers, often distinctly sapropelic, probably are as common in the Cretaceous lignites and sub-bituminous coals as in the Paleozoic coals, where they may frequently be observed, being sometimes of considerable thickness and purity even among the anthracites.[1] In the Paleozoic coals, which are more or less altered, the sapropelic layers, usually of a duller color and very hard, are often known as " hard coal " and as " bone." The principal coal beds of the Illinois field are generally capped in the mining areas by black sapropelic shale carrying marine shells, though sparsely supplied with macerated vascular plant matter of a more indestructible nature. Though sapropelic matter is apt to be present in " bone " coal it is not indispensable. The latter is regarded by Potonié as resulting from current action washing and reworking peaty material, which becomes thoroughly mingled with fallen plants as well as mineral sediments.

Everybody who has burned coal has probably observed that the ordinary coal, whether " bituminous," lignite, or anthracite, usually exhibits large quantities of the remains or refuse of vascular plants, of which only small fragments of the harder parts are preserved. The latter often constitute distinct woody layers, some of the pieces being rarely of very large size. In these coals the softer tissues have become obliterated through the macerative process and have doubtless contributed to the fundamental matter (liquid or " jelly ") in which the surviving and more resistant portions were bedded or suspended. The amount of this stercorary material varies greatly in different coals. To the nature and mode of occurrence of the woody matter mingled with the maceration products of softer and more

[1] In these coals it probably represents, in some cases at least, a stage of subsidence and temporary retreat of the land vegetation.

delicate tissues, in a way closely similar to that observed in many of the peats of the present day, is largely due the general belief that lignites and other coals have passed through an early stage homologous with peat formation.

Woody matter is particularly abundant in the lignites ("xyloid") of North Dakota and the so-called No. 1 coal of western Illinois. Such fragments are abundant in practically all the coals of the Interior basins. They are relatively scarce in certain other coals, such, for example, as some of the Texas lignites and certain "splint" coals of the Appalachian trough.

It is not improbable, however, that algal matter enters in varying proportions into the composition of most of our coals, though it may be obliterated by putrefaction or masked by the predominant woody matter, or obscured by the opacity of those coals altered by dynamic influences. What may be the effect of these obscure or even invisible ingredients it is not yet possible to estimate. Undoubtedly they have in many cases exerted a large influence in shaping the characters and qualities of the coals. It is possible, for example, that some proportion of algal matter may be essential to the best coking qualities. In fact the writer is inclined to attribute to algal matter the fusibility of our coking coals.

The possibilities of blended elements in the formation of the "fundamental matter," and the relation of the latter to the woody material will be better appreciated after a consideration of the macerative and coalifying process. In general, an increase in the amount of recognizable vestiges of higher vascular plants is to be seen as we pass through the series from the pure alga coal to the ordinary "bituminous" coals or lignites. Though algæ may not be recognized optically in some of the examined cannel and cannel-bituminous intergradations, their original presence is, nevertheless, indicated in many cases by both the chemical analysis and by the behavior of the coal in combustion. For the observations made thus far tend, in the interpretation of the writer, to establish a fusion of the coal in combustion when the algæ are present in any considerable numbers. This is a question that should be fully put to the test.

Most paleobotanists and chemists still treat the fragments of carbonized wood or natural charcoal, the so-called "mother-of-coal," which form layers in so many of our "bituminous" coals, as the remains of cinders, the work of forest fires, which have either been washed into the accumulating mass of vegetation in the peat bog or swamp, or partially burned on its surface. With this interpretation the writer disagrees. The phenomena of vegetable decay and accumulation as witnessed notably in peat bogs at the present day appear to justify the belief that these fragments of wood, or bark, often rounded and waterworn, owe their form and condition more or less directly either to a partial dry rot of the woody matter under subaerial conditions before immersion or, as seems more probable, to temporary exposure of the coal-forming accumulation to the air, the results being largely the same. The great amount of the charcoal, often in repeated layers, the large size of some of the fragments, the mutual relations of the fragments in the same layer and the action of the fundamental jelly on the fragments, appear to invalidate the cinder hypothesis. Furthermore it is not difficult, in the abundant charcoal layers which form so large a part of the coals of southern and western Illinois, and along the western margin of the Appalachian coalfield in eastern Kentucky, to find large numbers of pinnæ and pinnules of even the more delicate types of *Pecopteris* lying in the midst of the pieces of charcoal in layers more or less completely infiltrated or perhaps hardly cemented by the fundamental ground mass. These delicate fern laminæ are similarly converted to natural charcoal, even the nerves and villi of the pinnules being charred and in all respects like the associated fragments of wood. It is not probable that these pinnules so frequently were drifted and buried in their perfection among the coarse piles of wood after having first been charred by forest fires on the land; or that they mark fire-swept bogs from which the ash layers were removed. On the contrary, it may be more reasonable to conclude that the peculiar preservation of both wood and fern lamina has to do with the conditions of water level, concentration, septicity, etc., of solutions in which the delicate as well as coarser fragments became immersed.

The subject of the kinds and proportions of the antecedent organic matter contributing to the formation of the various kinds of coal, and the determination of the consequent special qualities and adaptations, is one deserving most serious and thorough consideration, notwithstanding the apparently insurmountable difficulties encountered in the examination of the Paleozoic and more altered Mesozoic coals of the humic type and the small encouragement for success, even in a partial degree. Yet such an investigation, if skillfully and patiently prosecuted with every aid that chemistry may lend to microscopical technique should throw additional light, not only upon the mechanical composition and development of the higher grades of lignites and "bituminous" coals, but, perhaps, also on the peculiar qualities of the gas and coking coals.

CONDITIONS OF DECOMPOSITION, OR COALIFICATION.

The ordinary process of coalification of an accumulation of organic débris embraces two stages of prime importance: (*a*) The putrefaction stage, which is, at least dominantly, biochemical; and (*b*) the alteration or metamorphic stage, which is dynamochemical, being induced and regulated, in the main, by geodynamic influences. The latter embraces phenomena ranging from pressure-dehydration and lithification, to graphitization.[1]

The most essential feature in the coalification of organic débris is the de-oxygenation and de-hydrogenation of the vegetal matter. This takes place under varying environmental conditions, beginning with the biochemical changes, or putrefaction, and continuing under dynamic influences, the more salient result of the latter being known as progressive devolatilization. Except in exceedingly rare instances of powerful thermic, or chemical action, the first step in the coalification of vegetal matter is invariably accomplished by fermentation or maceration which is interfered with in many ways before its final arrest as the result of

[1] The initial process is sometimes accidentally cut short by some catastrophic cause, such as sudden exposure to hot eruptive rocks, in which case the scope of the subsequent process is extended. In such cases the fuel products are often different.

exclusion of free oxygen or the development of ascepticism in the surrounding medium.

It was, perhaps, the most important of the brilliant achievements of the lamented Renault to show conclusively that in times past, just as at present, the fermentation and decomposition of organic tissue, whether vegetable or animal, was chiefly accomplished through the vital activity of microörganisms, by far the most important of which were the anaerobic bacteria. Evidence of the work of bacteria in the decomposition of vegetable tissues, now found fossil, has been observed in so many cases, covering so many plant types, and dating from so many periods of geological time, as no longer to leave open to question its preëminence as a factor in coal formation.

Renault has clearly shown that in the swamp, lagoon, or peat bog, the plant tissues are attacked by insects, worms, amœboids, fungi, and bacteria, of which the last named are preëminently most effective, absolutely omnipresent, and always most persistent. The two first mentioned are chiefly instrumental in the mechanical dissociation of the tissues, while at the same time aiding the bacteria in penetrating to the different portions of the vegetable structure. In this work the fungi also were doubtless of especial assistance.

In the process of putrefaction, as described by Renault, the thinner-walled cells are first effectually corroded, while at the same time the protoplasmic contents, filled with bacilli, become at first yellowish and, later, gradually brownish and turbid, slowly coalescing and becoming flocculent as the disintegration and destruction of the intervening cell walls progress. If arrested in an early stage the accumulating more or less pasty mass may remain brown with a very large content of undestroyed tissues;[1] but if uninterrupted the process goes on until all of the softer tissues are disintegrated and decomposed, leaving only the most enduring and indestructible parts, such as the densest cells, fragments of cuticle and seeds, or spore envelopes immersed in a dark, subgelatinous plastic or liquid mass[2] the " fundamental matter "

[1] Brown peaty substance.

[2] Advanced stage in black peaty substance (mature).

or "fundamental jelly." If the bacterial decomposition progresses still further, all of the vegetable tissues are obliterated (amorphous); or, if there is access to air, even the "fundamental matter" is in turn broken up and converted into humus, etc.; or the destruction may be complete.

The first stage in the transformation or coalification of vegetal matter is thus shown to be distinctly a biochemical process. The nature and relative amounts of the resultant hydrocarbon compounds obviously depend upon the extent to which the decomposition has progressed; and this extent is, in turn, governed by a complex of factors, the principal of which are the amount of oxygen available, its possible replenishment at various times during the accumulation of vegetal matter, the relations of water level to the surface of the vegetal mass, the development of toxic by-products, and the action of diluting or transporting currents in removing the highly soluble or other decomposition products or, contrariwise, in concentrating the same. Naturally, the rate of vegetable accumulation is an important element, as is also the degree of destructibility of the ingredient vegetal matter.

Specifically, the cessation of the putrefaction process appears to be due to the extinction of bacteria by exhaustion of the available oxygen or through the development, as the result of their own activities, of humic, ulmic, tannic or other antiseptic toxic by-products, in such amount as to make it impossible for them longer to exist. Evidence of the same initial process is seen in every sedimentary coal, whatever its age, that has so far permitted of satisfactory microscopical examination. Also the fortunate discovery in France of a Permian silicified peat has furnished a most striking illustration of the similarity of the Paleozoic to the present phenomena of plant decomposition. Even in the bogheads, or alga-shales, the bacteroides appear in many cases to have been preserved still in their corrosion pits. They have been reported in Carboniferous cortices, Devonian trunks, woody tissues of all kinds, seeds, and even in fragments of Paleozoic bones and animal excreta.

The progress of the bacterial action; the completeness of the de-oxygenation of a part or all of the cellulosic, lignosic or proto-

plasmic matter; the kinds of the original animal and plant organisms; the solution and abstraction in part, or the concentration of the resultant compounds; the volatilization or confinement of the latter; all are very important though delicate factors in controlling the chemical composition and economic qualities of the fuels.

It should be noted that with the cessation of the destructive activity of the microörganisms, of which the anaerobic bacteria are presumably the most enduring, no further dismemberment of the vegetal or animal structures takes place. Whatever further alteration or metamorphism the coal-forming organic matter may experience through dynamic or chemical agencies nothing short of pressure, rock deformation, fusion, displacement by crystallization, or exposure to weathering, can cause further serious disaggregation of the remaining organic tissue or mechanical residues.

A profoundly important product of the initial process of coalification is the fundamental matter or jelly, the liquid putrefaction product, whose genesis is described above. This fundamental matter, of probably variable chemical constitution and contents, forms the amorphous ground mass of the coal. It is the binder that cements the particles and fragments of undisintegrated tissues as well as the included sediments. Ordinarily it not only envelopes the undestroyed woody matter, but it infiltrates the surviving tissues to a greater or less extent. The larger stems that have settled in the asceptic coal-forming mass or the larger fragments that have escaped disintegration[1] are usually more or less completely infiltrated with this fundamental jelly. Where the impregnation is complete we find dense, glossy, or jetty and shining (according to the progress of coalification) woody sections with conchoidal fracture. The flattening of these stems produces horizontal bands and elongated lenses, the brilliant layers in so many of the somewhat altered coals. At other times, when the disintegration of the hard organic parts is relatively complete, it appears to have concentrated in films or sheets of

[1] Many large fragments of wood appear to have been but superficially disintegrated before the arrest of bacterial action.

amorphous paste. In many instances the impregnation of the wood has been imperfect, penetrating in zones while other zones are dull and more porous; or even, in some examples observed by the writer, the impregnation intergrades to a charcoal or "mother of coal." The lowest coals of northern Illinois and Iowa are remarkable for the relatively small amount of the fundamental matter, some of the layers consisting of large amounts of the charcoal, in fragments of varying sizes, but slightly infiltrated and cemented so as to constitute dull and sometimes slightly brownish layers in the coal.

Obviously the density and behavior of the fundamental matter are widely influenced by the varying conditions of deposition and decay of the coal-forming organic material, by the concentration of its liquids, etc. In many of the sapropelic or alga-coals it appears to have had the consistency of a jelly, whence the name given by Renault and Bertrand. It was first shown by these authors that in the bogheads and bituminous shales the algal thalli, mineral sediments, fish scales, and small molluscan shells are held in suspense in various positions as though fallen into a gelatinous mass. A similar condition obtains in the oil rock at Plattville, Wisconsin.

To the writer it seems probable that the fundamental jelly of the purer sapropelic coals (bogheads) is derived largely through the disorganization of algæ of the same kind as those whose thalli form the bulk of the rock. Thus great numbers of thalli, of the micro-algæ, as well as other vegetal or animal matter, may have been sacrificed before the bacterial action was checked, either through the increasing toxicity resulting from their vital processes or by the exhaustion of the oxygen supply. One of the most remarkable and anomalous circumstances observed in this connection is the survival and excellent preservation of innumerable, most delicate, microscopical, one-celled, gelatinous algæ, which usually constitute the greater part of the rock substance, while only the indestructible parts, such as scales, teeth, bones, and shells, of the associated animals remain. The muscles, tendons, and even the skins are lost in the animal organisms which lived in the same waters. This practically complete oblit-

eration of the animal organisms may have been due, as it appears to the writer, either to a more rapid putrefaction of the animal tissues so that they were completely disorganized before the conditions arresting further biochemical decomposition were produced, or, as seems more probable, to a difference in the toxins developed. In the latter case the bacteria of the kinds which accomplished the destruction of the animal forms may not have been susceptible to the toxicity caused by the action of the plant bacteria in the surrounding algal matter. Thus the animal bacteria may have completed their work after the extinction of the plant bacteria beneath the surface of the rapidly increasing organic accumulation. The writer is disposed also to believe that the bituminous elements derived from the fully decomposed animal remains have participated to a very important extent in the infiltration of the thalli of the undestroyed algæ, thus enriching the latter with combustible matter of a distinctly bituminous character. The enrichment of the algal matter in bitumen as the supposed result of a selective attraction exerted by the latter, was pointed out some years ago by Renault and Bertrand, and has very recently found essential corroboration in the analytical examination of various sapropelic rocks by the German chemists,[1] Stremme and Späte.

It has been noted that our ordinary lignites and so-called bituminous coals are derived predominantly from the tissues of vascular plants, fragments of which are still nearly always plainly in evidence. The structure and mechanical composition of these coals afford good grounds for the belief that the initial stage in the coalifying process is, on a grand scale, not widely different from that of ordinary peat formation with varying conditions and degrees of decomposition at different levels and consequent differences in the amount and kinds of surviving tissue fragments, the latter being cemented together, enveloped by, suspended in, or even completely impregnated by a maceration product constituting the " fundamental matter " or " jelly " of the ground mass. The process of decomposition appears to have been in-

[1] *Zeitschr. f. angew. Chemie*, October 25, 1907; *Monatsb. Zeitschr. d deutsch. geol. Gesell.*, July, 1907.

distinguishable from that witnessed to-day in the low peat bog and coastal swamp. The mode of occurrence and relations of tissue fragments, "mother of coal," and bright, or vitreous-looking jetty lenses, or layers, are, allowing for loading-pressure, and other metamorphism, approximately the same whether in lignites, "bituminous" coals, or anthracites. It has also been observed that in lignites, "bituminous" coals, anthracites and peats, we find sapropelic (alga) strata, amorphous layers, and earthy (humus) layers, in accordance with the phenomena that may be seen at the present time when there is change of water level, exile of vascular plant life, subærial exposure, tidal marsh, or even estuarine conditions. Between the sapropel-forming, or open stagnant water condition, and the vascular plant formation, there is every intergradation. Alternation may occur in a single bed.

Just as, however, the typical plant peat now in process of formation is characterized by its ulmic or humic acid compounds, so, evidently, were the similar peat homologues of the past. In fact, the xyloid lignites and other xyloid coals exhibit a distinct alliance with the humic or ulmic acid series, their composition being *high* in *oxygen* and relatively low in hydrogen. The ordinary lignites and common so-called "bituminous" coals, which bear evidence of predominantly vascular plant origin, are therefore in strong contrast with the typical alga or sapropelic coals and shales which, being more distinctly and truly bituminous in composition are on the other hand, *high* in *hydrogen* and relatively low in oxygen.[1]

The contrast in chemical composition between the sapropelic and the so-called bituminous coals may be illustrated by the following analyses, the first of which represents the Kerosene shale, a nearly pure alga-coal, from New South Wales, while the second shows the composition of an air-dried splint from Miller's Creek in eastern Kentucky. The real differences between these two coals become more apparent when the carbon ratios are taken into consideration. Both are Paleozoic.

[1] In the more altered or advanced (dynamic) stages of coal formation, *e. g.*, the Paleozoic coals—the contrast in oxygen is more obvious.

(1) H 9.63, C 76.61, O(+N)2.87, Ash 10.89, $\frac{C}{H}=7.95, \frac{C}{O+N}=26.69.$

(2) H 5.35, C 78.99, O 10.83, Ash 2.82, $\frac{C}{H}=14.76, \frac{C}{O}7.29.$

With the first of the analyses given above compare No. 3, which represents the bituminous filling of a Cordaites pith in the Permian shales at Margenne, France; with No. 2 it is interesting to compare No. 4, a conventional formula for ulmic or humic acid.

(3) H 10.39, C 85.02, O(+N)4.59, $\frac{C}{H}=8.18, \frac{C}{O+N}=18.52.$

(4) H 3.85, C 65.31, O 30.83, $\frac{C}{H}16.96, \frac{C}{O}=2.11.$

The above illustrations might be supplemented by an indefinitely long series, in which the distinction between the sapropelic (algal and gelosic) and the humic coals would be observed, though the differences are not usually so distinct as in the pure types cited. Mingling of ingredient organisms and consequent intergradation between the two groups of fuels naturally decreases the degree of contrast. It is important to bear in mind that alteration or metamorphism of the peats, lignites, etc., tends to emphasize the humic-bituminous distinction, though anthracitization appears to efface the contrast. The alga or sapropelic coals are the actually bituminous coals (enriched by bitumen), while the ordinary so-called "bituminous" coals really grade toward the humic (or ulmic) type instead.

Attention has already been called to the relatively rapid and complete disintegration of the animal matter in the sapropelic deposits, while in certain cases, at least, incredible numbers of gelatinous algæ have not only largely escaped the putrefaction process, but, according to the writer's interpretation, have probably absorbed more or less of the bituminous products of the decomposition of the associated animal organisms. This forcibly suggests that the algæ, which almost certainly have exerted an attraction for certain bitumens of extraneous origin, may have played the important rôle, first, of storing up some of the hydro-carbon products of the decaying animal matter; and, later, under dynamic influences, of releasing a part, at least, of the stored, as well as,

presumably, of their own original contents in the form of petrolic or gaseous hydrocarbons. There is little doubt in the mind of the writer that the oils and gases of the Mesozoic and Tertiary, as well as of the Paleozoic, are directly derived, in most cases at least, from dynamic distillation of algal débris, though in part originally of animal origin. In the generation of the petroleums from many of the Devonian, Carboniferous and Tertiary terranes it would seem that the algæ may have had less aid from original animal associates than perhaps in the Trenton or middle Cretaceous. The question is an interesting one, requiring further research though its investigation is difficult since it must be rare that the micro-algal life has been so inexhaustibly fecund that many specimens have escaped the agencies of decay so as to be certainly recognizable microscopically in a rock section. In most cases the tissues of both animal and gelatinous vegetal organisms have, perhaps, been entirely obliterated.

An important point to be borne in mind is that the attractive selection of the bitumens and the consequent enrichment of the algal matter appears to have been accomplished during the first or biochemical stage of coalification. It may also be noted that the conditions and duration of the putrefaction process in this stage were capable of determining whether a lignite should at the initial point be brown or black, xyloid or decomposed, just as they direct these features in the peats of to-day. The transformation of brown lignites into sub-bituminous, bituminous coals or anthracite results from the dynamo-chemical processes.

An interesting problem deserving special study concerns the conditions and possible extent to which woody and other non-algal plant tissues may be bituminously infiltrated under ordinary circumstances of coalification.

PART TAKEN BY DYNAMIC AGENCIES IN COALIFICATION.

In the preceding pages attention has been confined mainly to the initial stage of coalification *i. e.,* the decomposition of the organic matter through the agency of microörganisms, among which the anaerobic bacteria are primarily indispensable. This process, which is essentially *biochemical,* probably leads no fur-

ther than the formation of peats, humus, recent sapropelic deposits, humic concentrates, etc. It remains to consider the second, or *dynamo-chemical* stage of coalification—the transformation, as the direct or indirect result of dynamic influences, of the coalifying material into lignite, "bituminous" (humic) coals, anthracite, etc.

At the outset it must be remarked that among paleobotanists themselves a wide difference of opinion exists as to whether the succession, peat, lignite, "bituminous" coal, semi-anthracite, etc., is strictly lineal, *i. e.,* whether the substance of our lignites, "bituminous" coals, and so on, has ever passed through a peaty stage or condition, a lignitic stage, etc. Thus Renault and Bertrand and their followers, while admitting that pressure and other dynamic influences have doubtless produced various important alterations, insist that the differences between the great groups of coals are not due to metamorphic alterations, but to the character of the ingredients, differences in geological conditions of deposition, and the nature and extent of the initial biochemical processes. They urge that the coal-forming matter in the Cretaceous, for instance, passed directly to lignite by reason of its peculiar original organization; because the atmospheric composition or the aqueous medium may have conduced to products different from those of recent times; or on account of the qualities of the bacteria which may have belonged to different species possessed of different powers of persistence or leading to the generation of products different from those of later geologic times.

It is doubtless true that some or all of the modifying influences or conditions enumerated above were actually in operation to produce results differing somewhat in various periods. Also the discovery of the relations of ingredients to fuel qualities in the oil shales, bogheads, and cannel coals, cautions us to suspect the existence of other cases of important relations between the characters of the coal and the original organisms, or the conditions of accumulation, etc. But that these differences are sufficient directly to determine the formation of lignite, peat, or

semi-anthracite, for example, appears, at least to the writer, far too improbable to deserve serious consideration.

The paper coal of Tovarkovo, which consists of the brown flexible cuticles of a Lower Carboniferous Bothrodendron stuck together in a humic acid paste, is perhaps nearest comparable to a modern peat that is scarcely altered. The geological conditions surrounding a lignite of Liassic age that has survived in Austria are unknown to the writer, but it seems to him that the explanation of its survival as lignite is to be looked for in an absence of post-Liassic regional thrusting and metamorphism under loading in that locality. As for the effects of dominance of resinous vegetation in the formation of a coal it must be admitted that, though the gymnosperms were abundant in the Upper Cretaceous, they specially abounded in association with the generally more altered coals of the older Mesozoic. The writer's observations go to show that the ordinary gymospermous resins so frequent in the brown coals and darker lignites of the Upper Cretaceous become granulose, brown and spongy, finally disappearing with the progressive alteration (metamorphism) of the same coal bed in the same district. The Paleozoic coals, probably as the result of alteration, give little evidence for or against direct resinous constituents. On the other hand high grade bituminous coals, and also anthracites whose advanced stage of coalification (alteration) is obviously the result of dynamic influences are found in the Cretaceous and even the Tertiary.

In connection with the subject of the effects of dynamic influences on peats, lignites, etc., and the susceptibility of the latter to alteration to bituminous coals, etc., it may be of interest to cite the point of view of an eminent organic chemist: Donath[1] after pointing out that brown lignites and bituminous coals differ chemically, argues that they are composed from different materials, and that the former cannot pass into the latter. He also adds the quite untenable conclusion that the ingredient vegetation of the Paleozoic bituminous coals was totally, or very nearly, lacking in lignin.

[1] "Zur Entstehung d. fossilen Kohlen," *Chem. Zeits.*, 1904, p. 954. See also: Donath and Bräunlich, *loc. cit.*, p. 953.

Accumulating observations in the field tend only to confirm the conclusions of some of the earlier paleobotanists, as well as of most geologists and paleontologists of to-day, that the anthracites, "bituminous" coals, and lignites are but metamorphosed peats, lignites, etc., though the duration of some of the intermediate stages may have been relatively short. The association of devolatilized fuels with jointing and highly developed cleavage is more than accidental. The same forces that assisted in further de-oxygenating the truly bituminous coking coals at Sunnyside in Utah or at Sopris in Colorado also gave them a prismatic structure almost identical with that of the Lower Freeport coal at Reynoldsville in Pennsylvania, or the Pocahontas and Sewell coals farther south.[1] The regions of Los Cerrillos in New Mexico, Electric in Montana, and Crested Butte in Colorado offer irresistible proofs of the efficiency of dynamic agents, chiefly rock pressure, in the regional metamorphism of coals. The brown xyloid lignites of North Dakota become black xyloid coals (sub-bituminous) as one approaches the scenes of greater alteration in the Rocky Mountains, where the coals of the same series become anthracitic and even graphitic, as the evident result of dynamic influences.

Local devolatilization, or coal metamorphism, is occasionally observed in immediate proximity to a dyke or other intrusive mass; but the effects of the latter are apparently confined to a very short radius, probably seldom exceeding 200 feet; and in most cases they differ from the results of regional metamorphism, the ordinary cause. The work of the former, though always interesting, is so restricted as to be comparatively insignificant from the economic standpoint.[2]

In the progressive devolatilization and consequent improvement by alteration of the coal as the result of dynamic influences

[1] As already suggested, the writer is disposed to believe that the fusibility of the coking coals may be dependent on the presence of a certain amount of sapropelic (algal) matter. The determination of this matter by optical means is, perhaps, impossible on account of the alteration (metamorphism) undergone in bringing the coal to the condition requisite for coking successfully by ordinary commercial methods.

[2] The writer is disposed to believe that in far too many instances metamorphism has been attributed to intrusions when really due to thrust-pressure.

the writer believes the essential cause to lie, not in folding or faulting, but in the deeper-seated horizontal thrust movements, to which the folds observed in certain areas are merely local means of relief. There appear to be numerous instances in which local folding, even under heavy loading, has brought about no special devolatilization of the enveloped coals. He believes, to cite an example, that the progressive loss of volatile matter from coals in passing toward the eastward in the Appalachian basin is mainly due to a series of deep-seated thrusts, the most important being that attending the post-Carboniferous uplift; and not to the folding now to be observed in the anthracite districts and the eastern portions of the bituminous regions. In fact the relief obtained by folding or faulting has often permitted the retention of a volatile content higher than that found in contiguous areas of horizontal beds in which a stress, presumably less intense, was endured for a longer period. Every epeirogenic movement has brought its acceleration in the process of devolatilization. In this connection it may be noted that the loss of volatile matter in the anthracites of Pennsylvania has largely been credited to porosity of the interbedded non-carbonaceous sediments and to the presence of joints by which the gases were allowed to escape.[1] Though porosity undoubtedly facilitated the escape of the volatile matter it is probable that the real cause of that escape as well as of the joints lay in horizontal thrust pressure.

In connection with the subject of thrust pressure mention should be made of the coordinate influence and reciprocal action of gravity pressure or loading. Numerous observations tend to show not only that as a rule the more deeply buried coals, in the same vertical column, are further devolatilized; but also that coals by reason of their great sensitiveness to metamorphic influences and their consequent marked changes in chemical constitution offer, within certain limits of variability, a most delicate and flexible scale of criteria for the detection of minor differences in metamorphism (*e. g.*, pressure) even to a degree so small as to be hardly recognized in any of the elements of the associated sedimentary formations.

[1] Lesley, 2d Geol. Surv. Penna., Rept. Progress Chem. Lab., 1879, p. 153.

In the preceding discussion the chemical, as distinguished from the bio-chemical, changes incidental to coal transformation are assumed to be for the most part inseparable from the dynamic metamorphic agencies by which the writer believes them generally to have been induced. It is not denied, however, that in addition to infiltrations of quartz, lime, gypsum, etc., other purely chemical changes, originating independently of dynamic action have occurred. But those chemical changes brought about by dynamic action are by far more important and are absolutely essential, under ordinary conditions, in the reduction of the organic matter to coals of different grades.

The question as to the point at which the bio-chemical process ends and the dynamo-chemical (metamorphic), begins is one deserving further research. It is certain that the point varies widely under different conditions, and it is even probable that the two overlap in some cases. The variations on this point naturally influence the differences in the resultant coals.

Other questions deserving further inquiry are whether the lithification (and consequent partial dehydration) which results from loading pressure, and which is perhaps the first of the dynamic changes, absolutely precludes all possibility of renewal of bio-chemical action should there again be access through any agency of free oxygen;[1] also as to whether the chemical changes observed in the less mature coals, such as the brown lignites, on exposure to the air are to any extent bio-chemical. Some light will doubtless be thrown on these problems by the very interesting and valuable studies of peat bogs and peats now in progress at the hands of Professor C. A. Davis, at Ann Arbor.

Another greatly needed series of investigations relates to experimental tests of heat and pressure in the transformation of lignose, peat, lignite, etc. The records of those tests hitherto carried out are, it must be confessed, not only unsatisfactory,

[1] According to observations made by European paleobotanists the action of anaerobic bacteria ceases at no great depth in the ordinary peat bog.

It is, however, conceivable that in cases of arrested decomposition merely through smothering exclusion of oxygen, and possibly without development of complete toxicity, the anaerobic action may be susceptible of revival even at considerable depths.

for the most part, but also quite confusing in certain cases. Careful and thorough experiments in coal metamorphism should be conducted by some competent chemist in a well-equipped laboratory in accordance with standardized and improved methods. Such experimental work as that in rock metamorphism carried on in the geophysical laboratories of the Carnegie Institution should be extended and adapted to the study of coal transformation.

Neither the details of the organic changes that have taken place nor the actual chemical combinations present in the coal as finally mined and brought to the laboratory are definitely known. The conventional fashion among chemists of jumping from the cellulose or lignose formulas to such component weights in CH_4, CO_2, CO, H_2O, and H, as will have C and H in proper amounts to conform with the analysis of the coal is, in the judgment of the writer, not only fallacious but absolutely misleading. It appears little short of juggling with the quantities to make the figures come right. At the same time it is plain that, on account of the manifold vicissitudes to which the original organic matter is exposed from the time of its accumulation to the moment of exploitation, the relative amounts of the final residual matter must vary greatly, much of the ingredient material being totally destroyed, while the remaining proportions are reduced to obviously different stages or conditions. Some of it has gone into the probably variable composition of the fundamental ground mass and other amorphous liquid or volatile products; some of the cell walls were not completely broken down in the biochemical process, and these must have entered the dynamo-chemical period with compositions differing from that of the fundamental matter. In the formation of coal, as in other things, Nature is often wasteful in her methods.

In passing from cellulose or lignose through the series of peats, lignites,[1] sub-bituminous, "bituminous" and anthracitic

[1] Those coals of the Rock Mountain region whose physical characters, percentages of fixed carbon, and hydrogen-oxygen ratios are as high as those of the Paleozoic coals of Iowa, or Illinois, are just as truly "bituminous," and should be designated by the same term. It is unfortunate both to geology and to industry that these coals, some of which equal the best in

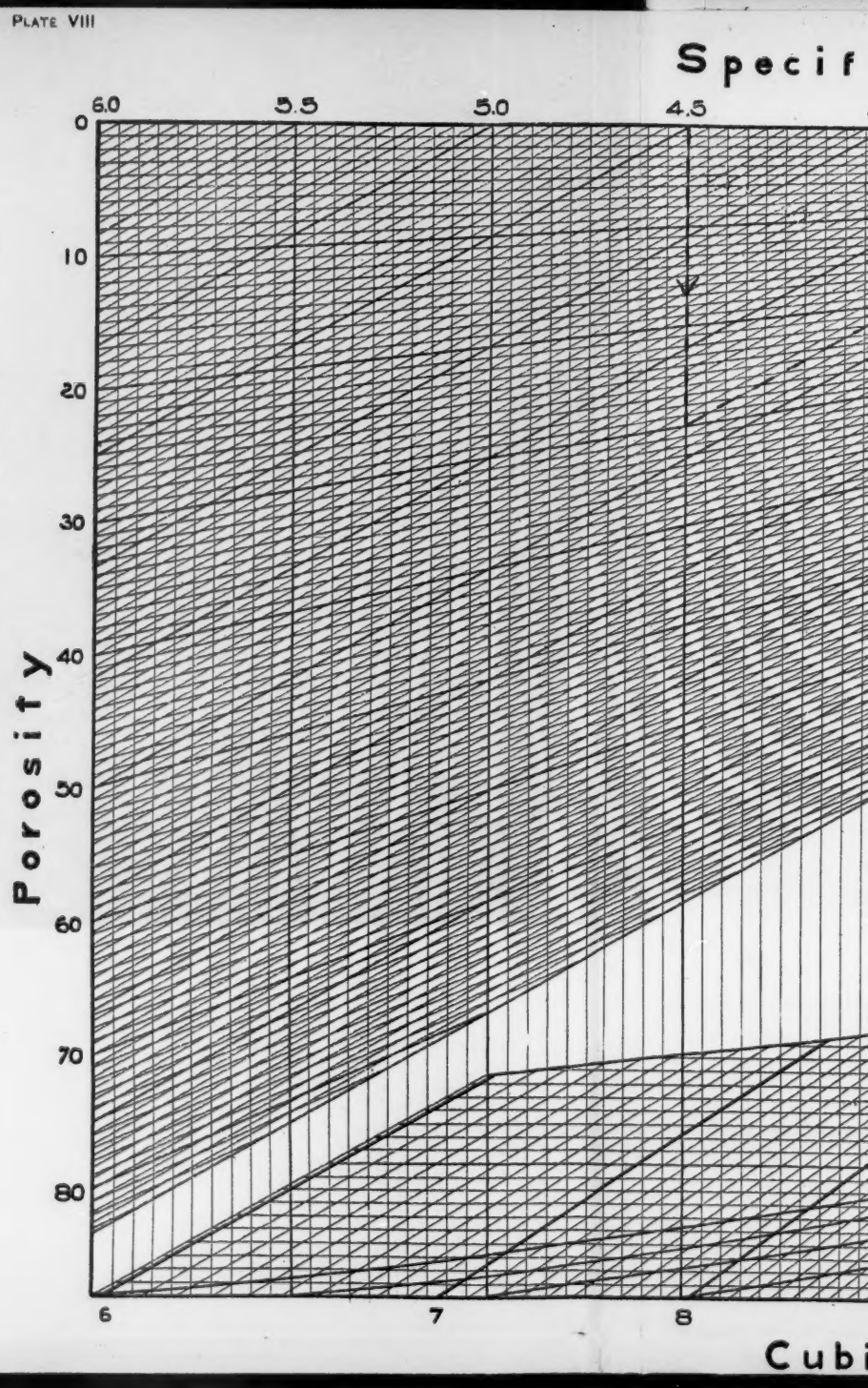
coals the essential chemical result of the transformation is the de-oxygenation and de-hydrogenation of the vegetal matter. Of these the reduction of the oxygen is, as pointed out by some of the earlier authors and more recently by Grout,[1] the more important. Through the bio-chemical and the metamorphic stages the curve of the oxygen ratio, though most marked in the formation of peat and brown lignite, declines in a well-rounded sweep traversing the lower and higher grades of bituminous coal until it approaches the semi-anthracites when it again pitches to the anthracites. The hydrogen loss, on the contrary, is very great in the formation of peat, and is still rapid in the transition to brown lignite, though after reaching the sub-bituminous coals it suffers very gradual diminution until the final rapid loss in anthracitization.

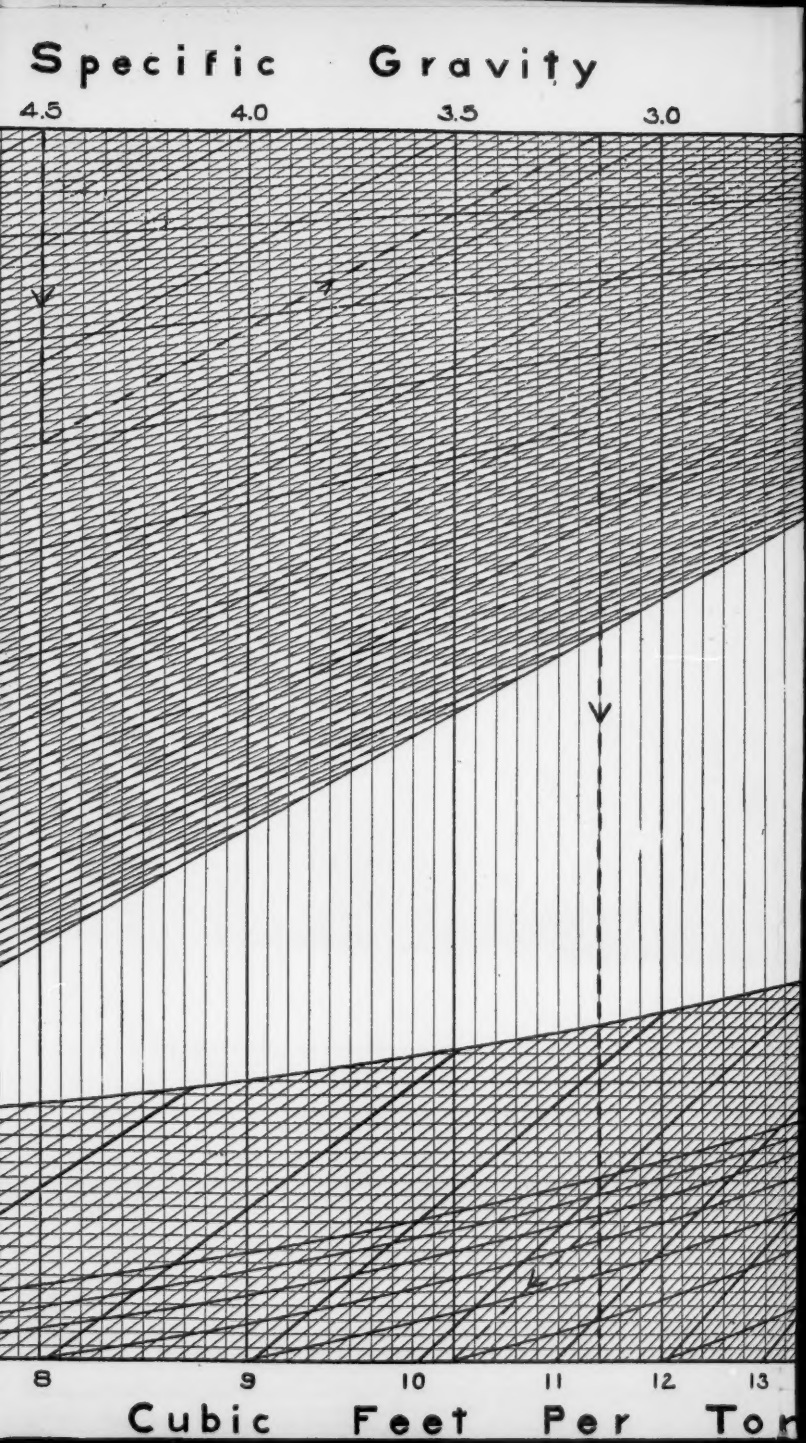
The degree of the de-oxygenation of the organic matter is the true index of the progress made in the formation of coal; and it is, at the same time, also the index of the efficiency of the fuel. For, other things being equal, the efficiency of the coal, as measured in B.t.u.'s increases precisely as the oxygen is eliminated, whatever the class of the coal. In a later paper the writer hopes clearly to show that the effect of the oxygen as an impurity impairing the efficiency of the coal is approximately the same as that of an equal percentage of ash, the anti-calorific values of oxygen and ash being nearly interchangeable; and that in general among the humic coals, from peat to semi-anthracite, the order of the efficiencies of the fuels, in B.t.u.'s, is essentially the order of the carbon-(oxygen plus ash) ratios.

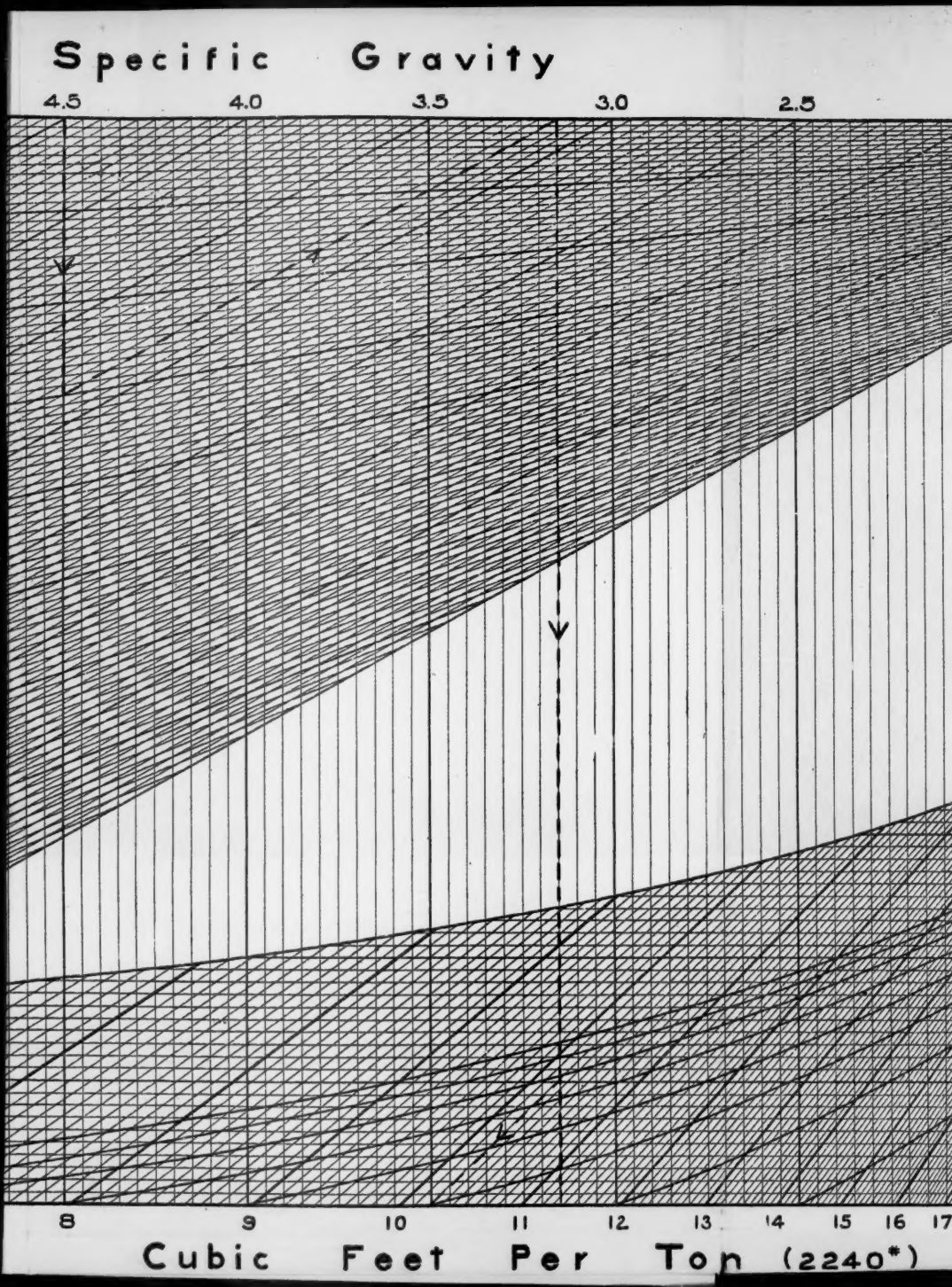
Ohio or Indiana, should for so long have been called "lignites" simply on account of their Cretaceous age.

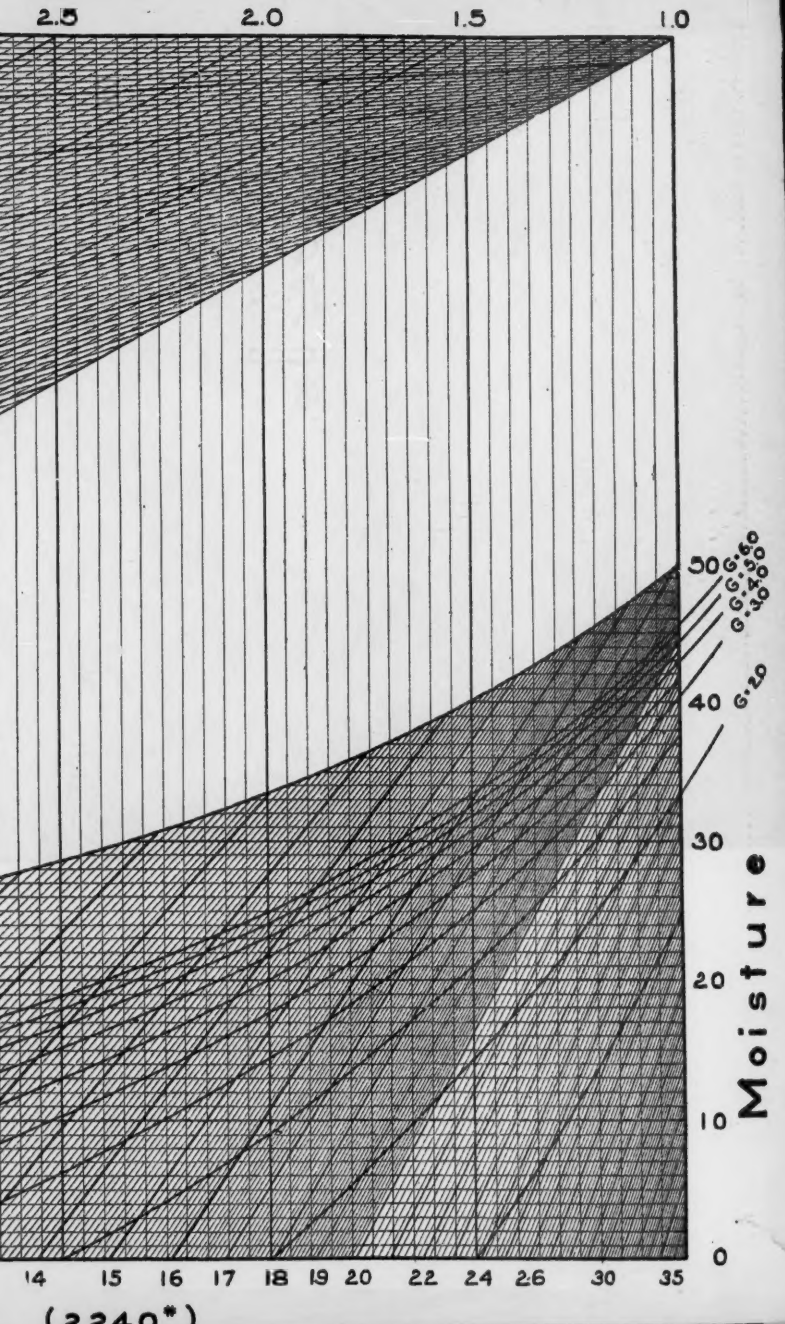
[1] ECONOMIC GEOLOGY, Vol. II., No. 3, 1907, p. 225.

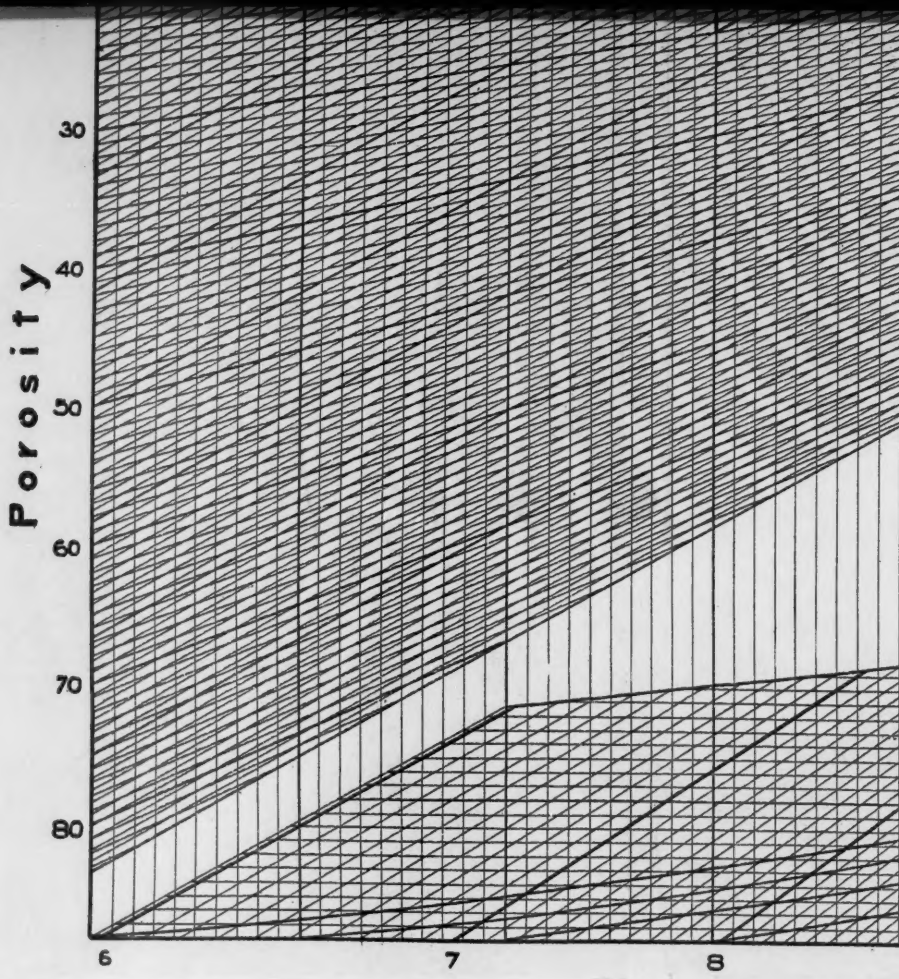
PLATE VIII




Specific Gravity
4.5
4.0
3.5
3.0
8
9
10
11
12
13
Cubic Feet Per Ton


Specific Gravity
4.5
4.0
3.5
3.0
2.5
8
9
10
11
12
13
14
15
16
17
Cubic Feet Per Ton (2240*)


2.5
2.0
1.5
1.0
50
40
30
20
10
0
G·60
G·50
G·40
G·30
G·20
Moisture
14
15
16
17
18
19
20
22
24
26
30
35
(2240*)



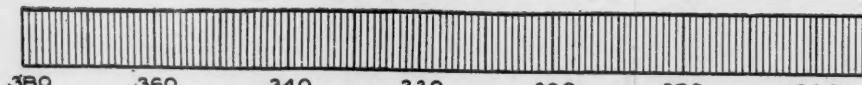
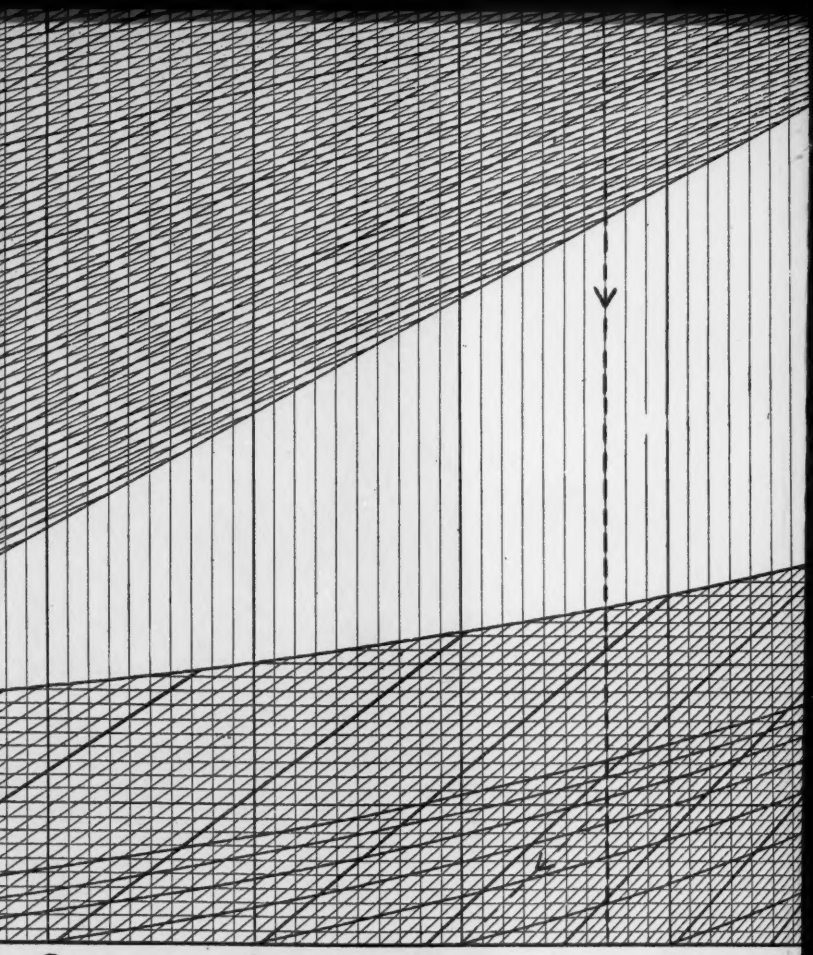


DIAGRAM ILLUSTRATING TH



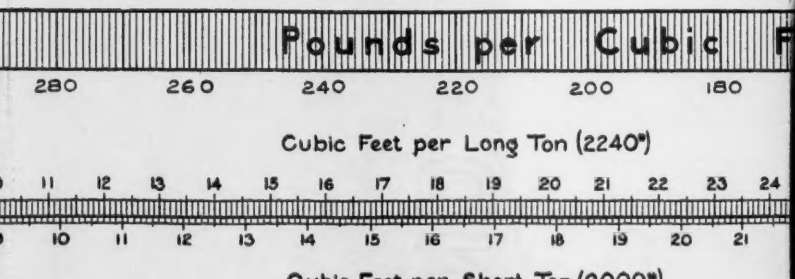


DIAGRAM ILLUSTRATING THE RELATION OF DENSITY, POROSITY AND MOISTURE TO THE SPECIFIC VOLU

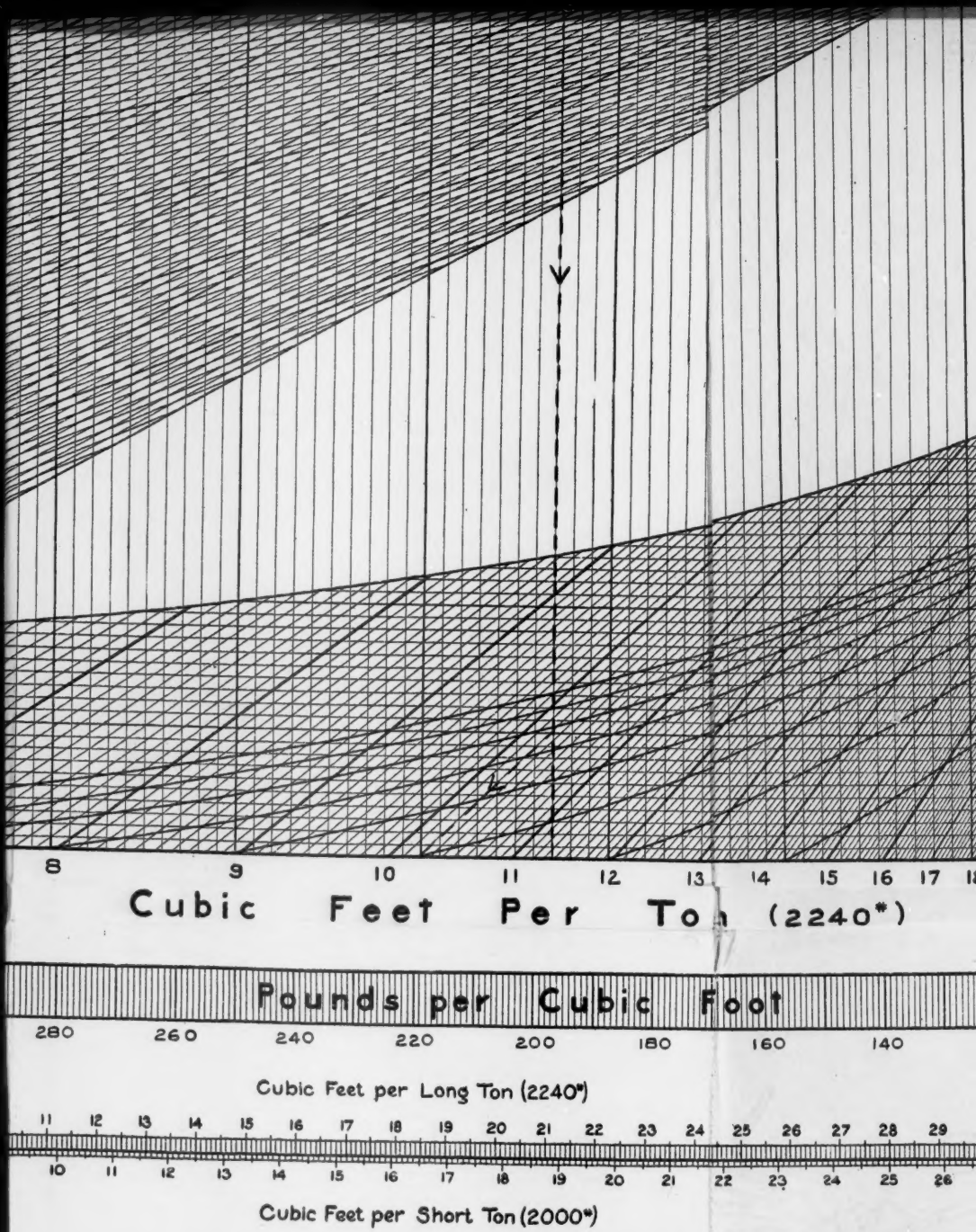
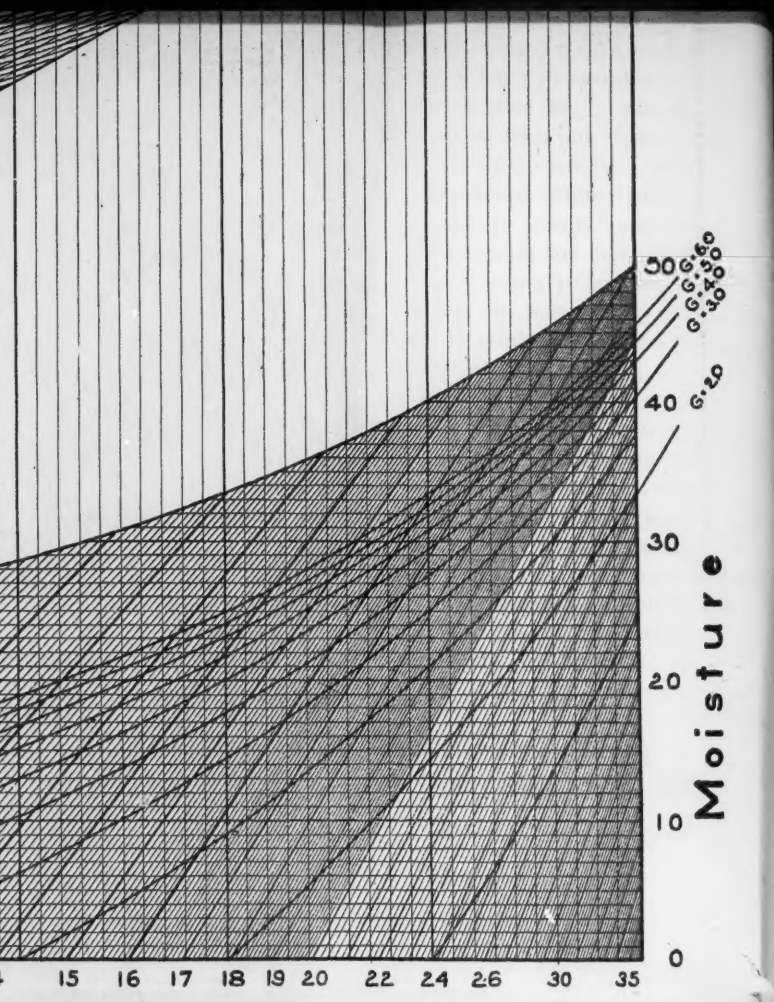
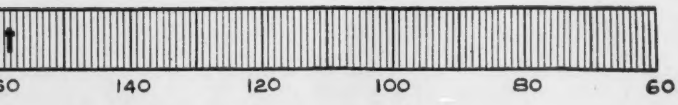


DIAGRAM ILLUSTRATING THE RELATION OF DENSITY, POROSITY AND MOISTURE TO THE SPECIFIC VOLUME OF ORES


50
40
30
20
10
0
Moisture
G·60
G·50
G·40
G·30
G·20
15 16 17 18 19 20 22 24 26 30 35

(2240*)


140
120
100
80
60

26 27 28 29 30 31 32
23 24 25 26 27 28

ORES

THE RELATION OF DENSITY, POROSITY, AND MOISTURE TO THE SPECIFIC VOLUME OF ORES.[1]

WARREN J. MEAD.

It is often necessary to know the cubic content of a material as it lies in the ground, in order to estimate the amount in place, or tonnage represented by a given excavation, or to compare different grades of ore. This cubic content is a direct function of: (*a*) True specific gravity of the material, that is, the specific gravity unaffected by porosity or moisture; (*b*) porosity of the material, in terms of per cent. of volume occupied by pore-space or voids; (*c*) percentage of moisture in the material, that is, the percentage loss in weight on drying at 110° C.

To facilitate the determination of the cubic content of ores the following diagram or graphic equation was devised (Plate VIII.) expressing the relation between these three factors and the number of cubic feet per ton. Actual determinations in the ground are unsatisfactory in that they do not show the individual effects of the three factors mentioned, especially moisture content which may vary widely at different times and places. By use of the diagram the three factors are considered separately, and their individual, relative, and net effects may be observed. The method was devised for the determination of cubic contents of Lake Superior iron ores, and results have been checked with a considerable number of empirical determinations by the mining companies. *The table is equally applicable to any ore or other mineral substance in the ground.*

USE OF THE DIAGRAM.

The operation of the diagram may perhaps be made clear most easily by applying a concrete problem by way of illustration.

[1] Published by permission of the Director of the U. S. Geol. Survey. Work done in connection with forthcoming final monograph on the Lake Superior region, now in preparation by C. R. Van Hise and C. K. Leith.

Given an ore with a specific gravity of 4.5, porosity 30 per cent., and moisture 10 per cent. Select a point on the upper edge of the diagram indicating the given specific gravity (4.5), from there move downward, as indicated by the dotted line, to the line representing the given porosity. (There are two sets of inclined lines crossing the upper part of the diagram; the less steeply inclined set, numbered at the left side of the diagram, indicates degree of porosity.) From this point move upward to the right along the more steeply inclined lines to the edge of the diagram. This point (3.15) indicates the *specific gravity as corrected for porosity.* From this point move directly downward to the lower edge of the diagram where the number of cubic feet per ton is indicated. This shows 11.4 cubic feet per ton of *dry material.* The factor of moisture has not yet been considered. When moisture is present the material is heavier and consequently the volume per ton smaller. To introduce this factor of moisture, move directly upward from the last point (11.4) to the horizontal line indicating the given percentage of moisture (10) and from this point down the inclined line to the lower edge of the diagram where the number of cubic feet per long ton is found to be 10.2.

At the lower edge of the plate is a transformation table showing the relation between cubic feet per long ton (2,240 pounds) and cubic feet per short ton (2,000 pounds). For example—10.2 cubic feet per long ton is equivalent to 9.1 cubic feet per short ton.

METHODS OF DETERMINING SPECIFIC GRAVITY, POROSITY AND MOISTURE.

The following methods of determining the above constants were found to apply very well to the Lake Superior iron ores, and may apply to other ores.

Specific Gravity.—To avoid confusion it may be well to define the terms *mineral specific gravity,* and *rock specific gravity* as used in the present discussion. As the term implies, by mineral specific gravity of an ore is meant the specific gravity unaffected by porosity or moisture, determined entirely by the mineralogical composition. The term *rock specific gravity* applies to the en-

tire mass of the material, and differs from the mineral specific gravity in proportion to the porosity of the material, and the moisture present. In making determinations of mineral specific gravity it is of course necessary to exclude all effects of pore-space and moisture. When the material is of a known mineralogical composition the specific gravity may be readily calculated from a chemical analysis of the material. This method is very satisfactory and does not necessitate any gravimetric determinations other than an occasional one as a check on the calculated figures.

When the nature of the material admits, determinations may be made on hand specimens by the common method of weighing first in air and then submerged in water. In this method care is needed to insure complete drying before weighing in air, and complete saturation before weighing under water. The former may be accomplished by prolonged drying in an air-bath at 110° C., and the latter by prolonged boiling in water under reduced pressure. The more porous the specimen, the more easily are both of the above operations accomplished. A third method, which has some points of advantage over the other two, is determination of the finely powdered and dried material by means of a specific gravity bottle.

Porosity.—Porosity is expressed in terms of per cent. of volume occupied by pore-space or voids. Determinations of porosity in hand specimens may be made by finding the weight of water absorbed in saturating a completely dry specimen. This measures the amount of water needed to fill the openings, which amount may be calculated in terms of volume by taking account of the specific gravity of the material. Given, mineral specific gravity, and moisture of saturation in terms of percentage weight, porosity may be calculated as follows:

$$P = \frac{M}{\frac{1 - M}{G} + M}$$

P = porosity,
M = moisture of saturation,
G = mineral specific gravity.

In unconsolidated material such as a large part of the iron ore of the Mesabi district, porosity cannot be readily determined from hand specimens, and it is necessary to resort to actual measurement of the volume of an excavation caused by the removal of a known weight of ore. From this determination of volume, together with a moisture and mineral, specific gravity determinations, porosity may be calculated, and the diagram becomes useful in showing the effects of fluctuation in moisture in an ore of uniform composition and texture.

Moisture is considered in terms of percentage of total weight. It is determined by noting the percentage loss in weight on drying at 110° C.

CONSTRUCTION OF THE DIAGRAM.

The following discussion of the derivation of the diagram is given with the idea that one desiring to make use of it would first wish to be assured that it rests on a rational mathematical basis.

The top and bottom lines of the diagram proper, labeled respectively, "specific gravity," and "cubic feet per ton," and connected by parallel vertical lines, constitute a transformation table by means of which the number of cubic feet per ton of a material of a given density may be at once determined (or *vice versa*) by moving vertically between the upper and lower edges of the diagram. Immediately below the edge of the diagram proper is a scale of pounds per cubic foot, which may be used by moving vertically downward from any point on the "specific gravity" or "cubic feet per ton" scales.

Effect of Porosity.—The effect of porosity is to decrease the density of a substance, hence rock specific gravity is less than mineral specific gravity in proportion to the degree of porosity of the material considered. To introduce the factor of porosity in the diagram, the upper line was extended to the right to the point indicating a specific gravity of zero (not shown on the diagram). The line at the left edge of the diagram was drawn perpendicular to the upper edge and divided into 100 equal divisions, representing percentages of pore-space. Each of the

points of the vertical "porosity" line was then connected with the point indicating a specific gravity of zero. Hence on moving vertically downward from any point on the "specific gravity" line, a succession of equally spaced lines are crossed indicating percentages of pore-space. To enable the diagram to automatically show the change in specific gravity resulting from a given porosity of a substance of known mineral specific gravity, a set of parallel lines was drawn, properly connecting points on the "porosity" and "specific gravity" lines. These lines were drawn parallel to the line connecting 100 per cent. porosity with zero specific gravity, and agree with the following formula:

$$G_r = G_m(1 - P)$$

where G_r = rock specific gravity, G_m = mineral specific gravity, P = porosity. The diagram then automatically shows the relation between mineral specific gravity, porosity and cubic feet per ton. To illustrate, a certain ore with a mineral specific gravity of 5.0 has 40 per cent. pore-space. Beginning at the point 5.0 on the upper edge of the diagram, move downward to the line indicating a porosity of 40 per cent., from this point move along the parallel inclined lines upward to the right, to the edge of the diagram, where the specific gravity as reduced by pore-space (rock specific gravity) is found to be 3.0; immediately below this point, on the lower edge of the diagram it is seen that the ore runs 11.95 cubic feet per ton, and 187.25 pounds per cubic foot.

Effect of Moisture.—The diagram so far takes no account of moisture, and hence is applicable only to perfectly dry material. Moisture when present in an ore or similar substance occupies the pore-space. When the pore-space is filled with moisture the material is said to be saturated. As the moisture occupies the natural openings in the ore, its presence affects the weight of the ore and not its volume, hence its effect is to increase the density and decrease the number of cubic feet per ton. Moisture is expressed in percentage of total weight.

Let D = density as affected by porosity.

$$\text{Cu. ft. per ton} = \frac{2{,}240}{D \times 62.4}$$

(one cubic foot of water weighs 62.4 pounds).

When moisture (M) is present the above equation becomes,

$$\text{Cu. ft. per ton} = \frac{2{,}240}{(D \times 62.4)(M + 1)}$$

The lower part of the diagram is crossed by a set of parallel horizontal lines indicating percentages of moisture, as shown at the right-hand edge of the diagram. Following the above equation, a set of inclined lines were drawn, properly connecting points on the "moisture" and "cubic feet per ton" lines. Given the number of cubic feet occupied by a ton of any porous material when *dry*, the effect of any percentage of moisture is indicated automatically by the diagram. For example, a certain ore when dry occupies 12 cubic feet per ton, it is desired to know the effect of 10 per cent. moisture. From the point 12 on the lower edge of the diagram move vertically upward to the horizontal line indicating 10 per cent. moisture, from this point move downward along the inclined line to the edge of the diagram, where it is found that the moist material occupies 10.8 cubic feet per ton.

Moisture of Saturation.—Up to this point it has been shown that, given mineral specific gravity, porosity and moisture content of an ore or similar substance, the diagram automatically indicates the number of cubic feet per ton. In many classes of ore the factor of moisture is the most variable of the three named above. Mineral specific gravity, and porosity of an ore determine the amount of moisture which it is possible for an ore to hold. This maximum, or moisture of saturation may be calculated as follows.

G_m = mineral specific gravity.
D = density of dry porous material.
P = porosity.
M = moisture of saturation.
$D = G_m(1 - P)$.

from which $P = 1 - \frac{D}{G_m}$

$$M = \frac{P}{G_m(1-P)+P}$$

substituting above value for P,

$$M = \frac{1-\frac{D}{G_s}}{D+1-\frac{D}{G_m}}$$

By substituting values for D and G_m in the above equation the moisture of saturation curves were constructed across the lower part of the diagram. These curves enable one to determine at once the moisture of saturation of any material, given the mineral specific gravity and porosity. Each curve corresponds to a certain mineral specific gravity, and the moisture of saturation is found by moving vertically from the point indicating the number of cubic feet per ton of the *dry* material to the proper moisture of saturation curve. For example an ore with a mineral specific gravity of 4.0 porosity 36.0 per cent., occupies 14 cubic feet per ton if dry—its moisture of saturation is found by moving upward from the point 14, to the curve $G = 4.0$, and reading the indicated moisture,—in this case 12 per cent. That is, 12.3 per cent. moisture would fill the pore-space of the material in question.

Excess of Moisture Handled in Mining.—It frequently happens in mining that ore as hoisted to the surface actually contains a larger percentage of moisture than it did before it was mined, it may in fact contain a percentage of moisture greater than the moisture of saturation of the unmined ore. This may be caused by the handling of broken ore on undrained mine floors. The ore after being broken down, has a much larger percentage of voids than before and hence a greater ability to absorb and retain moisture. The diagram is useful in this connection in showing, from determinations of specific gravity and original porosity of hand specimens, the moisture of saturation of the ore in place. This figure compared with the percentage of moisture of ore as it leaves the mine tells at once whether or not an unnecessary amount of water is being hoisted with the ore, due to improper drainage.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

THE LOCALIZATION OF VALUES IN ORE-BODIES AND THE OCCURRENCE OF SHOOTS IN METALLIFEROUS DEPOSITS.

ORE SHOOTS AT BUTTE, MONTANA.

Sir: The subject of "ore shoots" or "bonanzas" or whatever we choose to call the localized occurrences of relatively richer bodies in a vein or ore-deposit, is one of the most perplexing and one of the least understood of all problems relating to the geology of metalliferous deposits. Why there should be a selective action exercised by a mineralizing solution traversing a fissure in a uniform country rock, is a matter difficult of explanation. The usual forms and occurrences of these richer portions in ore veins are generally well known. Their importance in mine sampling, mine valuation, etcetera, is familiar to all who have had occasion to sample and study closely veins of the ordinary type. The subject has not received any especial attention in recent years, and, while there have been a great many new mines opened up, and many facts disclosed, it is doubtful if any substantial advancement has been made in the study of this most important problem.

Mr. J. D. Irving's article in the March issue of ECONOMIC GEOLOGY is a most interesting presentation of the important phases of the subject of ore shoots, and it is hoped that it will serve to stimulate further study among geologists and mining

engineers along these lines. At this time, I do not wish to enter into the discussion of Mr. Irving's paper, but desire merely to note a few instances or examples of ore "shoots," which have come under my personal observation.

The presence of well-defined ore shoots in the copper veins of the Butte district was not recognized in the earlier history of the camp; and it appears that they were of doubtful existence as late as the year 1897, when the Butte Special Folio was issued by the United States Geological Survey. This may be accounted for in a large measure by the fact that most of the earlier mining operations were upon what are known as the older "East-West," or "quartz-pyrite" veins which are of a remarkable width and uniformity in mineralogical character. The more prominent of these have been stoped for hundreds or even thousands of feet continuously along their strike, showing little, if any disposition to develop shoots. There is, of course, a considerable variation in content of the valuable metals in different parts of the veins, but such may not be properly designated as shoots. Later developments, however, have brought new facts to light, and in at least two vein systems which are known to be younger geologically than the Anaconda or East-West system, the occurrence of ore in large irregular bodies, is a most characteristic feature. These later veins have been termed fault veins, because they are known to cut and displace the earlier veins, and because of their physical character. They consist mainly of crushed country rock which may be either granite, aplite, or quartz-porphyry, carrying small amounts of quartz and iron pyrites either as finely disseminated material, or in the form of small stringers or scarf-like masses irregularly scattered throughout the crushed country. The fault, or crushed zone is usually narrow, varying in width from five to twenty feet, exhibiting one or more well-defined planes of movement marked by a dark blue or black, tough clay one quarter inch to five or six inches thick. The above description applies to the barren stretches of vein between the ore shoots.

Some of these fault veins have been opened up on strike for

more than a mile, and at intervals which are indeterminate excepting by actual development, immense ore shoots have been encountered. These ore shoots, which are quite irregular in form, show great variations in size from mere bunches or pockets, up to great ore bodies over a thousand feet in length and of unknown height, in some instances fifteen hundred to two thousand feet vertical height having been developed with no bottom yet known. The thickness of the ore varies from nothing up to twenty feet, or the entire width of the fault zone. In the latter case, there may be shown a complete replacement of the crushed country rock by ore minerals, leaving but little evidence of the fault character of the original fissure.

The mineralogical content of these shoots is chiefly quartz and iron pyrites with smaller amounts of zinc blende and the copper minerals, chalcocite, enargite, bornite, covellite and chalcopyrite, the last named being of rare occurrence. As far as known to the writer, there is no method of reasoning by means of which the position or extent of these shoots can be foretold. They usually fade out on strike within a distance of fifty feet or less; although the limiting boundaries are not always well marked. There appears to be no regularity to the pitch of the shoots, that is, there is no common direction of pitch. There are many examples of what I would term " shoots within a shoot," or localized areas of rich ore within the main ore body as above outlined. There are also enrichments within the larger shoot due to mineralization along cross faults which are only local and do not extend beyond the boundaries or walls of the main fault. I have observed many examples of this character, indicating continued movement, or readjustment of the ore body, or other material within the fault zone during the period of vein forming action. Such internal transverse fissures may be filled by richer ore, or there may be an enrichment of the earlier formed ore adjacent to the fractures, or both conditions may be present. Longitudinal fissuring has occurred during the period of mineralization, and has had an important influence upon the nature of the ore body, but these effects are not readily determinable, as the age of such fissuring is not generally evident.

The conditions under which these ore shoots were formed are somewhat obscure, and no attempt will be made at this time to enter into a discussion as to their genesis with reference to their mineral content, that is, whether the ores, either wholly or in part, were deposited from ascending or descending solutions, traversing the fault fissure. A few observations regarding the extent to which the large fault fissures in the Butte district have acted as channels or passage ways for underground mineral bearing solutions, may be of interest. In the first place, it is evident from the thoroughly altered condition of the crushed granite at all points along these faults, that there must have been, at an early period, a reasonably free circulation of waters throughout the entire extent of the fault zone, producing this intense alteration. But, as these fault zones are explored by mine workings, long distances along the strike are found to be absolutely dry and barren or ore, while the ore shoots themselves are usually wet. These facts indicate, to my mind, that the present positions of the shoots represent the channels or zones through which the ore-bearing solutions traveled. The concentration of all the solutions traversing the fault into these channels, I believe, to have been brought about through the development, by continuous earth movements within the fault planes of impervious barriers composed of altered, clayey, crushed granite and attrition clay or gouge. The presence of this impervious material directed the circulating waters along lines of least resistance. In other words, solutions which at first traversed the entire extent of the fault fissure, were corralled, so to speak, and confined to more definite zones, while the walled-off or excluded portions gradually became dry.

The location of the ore shoots was therefore determined in part at least by the physical nature of the country rock composing the fault zone. The size and richness of the ore bodies may have been influenced to some degree by the cutting off, or I might say damming back, of the mineral solutions, through the later development of impervious material along or within the fault zone.

I have seen many examples of this phenomenon in various

parts of the Butte district where the clay and crushed granite of a fault acted exactly as a dam, holding back enormous quantities of water. On the 1000-foot level of the Six O'clock shaft a crosscut was driven for several hundred feet, directly under the foot wall of a large fault zone, in an absolutely dry, unaltered granite. After passing through the thick clay and crushed granite foot wall, a perfect reservoir of water was encountered, the whole mass of fractured rocks for a hundred feet or more being thoroughly saturated. A condition exactly similar was noted on the 1,100-foot level of the Butte and London mine. Alternate wet and dry areas along faults in Butte are characteristic. The wet zones often encountered when drifts intersect faults are usually due to the presence of shattered granite or vein near the fault, and not necessarily from the water traversing the fault fissure itself. Fractured or sheared granite but slightly altered or shattered quartz veins appear to offer the most ready passage for underground waters.

That the immense quartz-pyrite veins of the old East-West system of copper veins in Butte were formed along shear zones having but slight displacement, I have no doubt. Repeated observations show that these earlier fissures are later than and intersect the quartz porphyry dikes, but the displacement is very slight, even along the largest veins. The wonderful continuity and uniformity in size and character of these veins are due to the very significant fact, that they were not formed along fissures of extensive movement, such as I have described above, but were fracture zones along which there was insufficient movement to develop the impervious fault material so characteristic of the larger faults. A free general circulation was thus permitted throughout the entire extent of the fracture zones, finally producing the extensive quartz-pyrite veins, of which the Anaconda and Syndicate Lodes are the best examples. Later cross faulting has cut and displaced the fault veins above described, also the veins of the Anaconda or East-West system, resulting in many instances, in an enrichment of the fractured veins adjacent to the intersecting fissures.

The above is offered merely as a possible explanation, to account for the position of the ore shoots in the fault veins of the Butte district. The circulation of underground waters through fault fissures of the character above described does not appear to have been in this district as free and extensive as is generally supposed. During the period of faulting, there was more or less fracturing of the older veins, together with strike faulting along them. The passages for the circulation of mineralizing solutions thus afforded in and along these older veins, were far more important and contain more ore than the main fault fissures themselves.

RENO H. SALES.

BUTTE, MONTANA,
May 1, 1908.

THE RELATION BETWEEN CERTAIN ORE-BEARING VEINS AND GOUGE-FILLED FISSURES.

Sir: In the study of ore deposits in the western states my attention has been directed more than once to fissures which, although filled with soft gouge and presenting clear evidence of recent movement, yet appear to have antedated, as regards their initial formation, the ore-filled fissures in their vicinity.

The literature of ore deposits affords several examples of barren gouge-filled fissures which are as old or older than accompanying fissures filled with ore. The famous silver veins of Andreasberg, in the Harz Mountains, are confined to a wedge-shaped block of ground between two strong faults, called by the miners *ruscheln,* or rotten veins.[1]

Lindgren,[2] in describing the De Lamar mine, near Silver City, Idaho, states that "It has long been the opinion of those connected with the mine that the veins are faulted by the clayey

[1] Beck, R., "Erzlagerstätten," Berlin, 1901, pp. 288–290; also English translation by W. H. Weed, New York and London, 1905. See also Hoppe, O., "Uber die mechanischen Vorgänge im Innern und an der Oberfläche der Erde mit Berücksichtigung der sogenannten 'faulen Ruscheln' am Harz," *Zeitschr. f. Prakt. Geologie,* Vol. 15, 1907, pp. 139–143.

[2] "The gold and Silver Veins of Silver City, De Lamar, and Other Mining Districts in Idaho," Twentieth Ann. Rept. U. S. Geol. Survey, Pt. 3, 1900, p. 159.

rhyolite or the 'iron dike,' and that consequently their continuation might be found beyond this crushed mass, but this belief is probably not justified. . . . When the fissures which were to receive the mineral-bearing solutions were broken open, the force which readily shattered the brittle rocks spent itself in vain against the tough clayey 'iron dike,' and thus the veins are apparently cut off by the latter. . . . This clayey wall acted as a barrier, damming the solutions and causing the more abundant deposition of mineral matter below it; at the contact, indeed, the most intense action took place and the richest ore bodies were found."

The Castren fault in the Gold Coin mine, in the Cripple Creek district, is probably also a fissure which is older than the ore that ends against it.[1]

Notwithstanding these and other recorded examples the subject of antecedent gouge-filled fissures does not appear to have attracted much attention from students of ore deposits and certainly has not received adequate treatment. The following notes, relating to deposits in the Cœur d' Alene lead-silver district of northern Idaho,[2] are presented in the hope that they will suggest lines of observation and call forth some discussion, particularly as regards the criteria for the recognition of the antecedent or subsequent character of gouge seams.

The Standard-Mammoth one of the most productive lodes in the Cœur d' Alenes, strikes from 10° to 15° north of west and has a known length of approximately 2,000 feet. On the east the lode terminates abruptly against a fissure which may be called the Standard fault. On the west the ore body is not so sharply limited, the ore becoming narrower and the lode fissures less distinct in this direction. Apparently there was never much displacement along the Standard-Mammoth lode and such movement as took place diminished gradually toward the west. The fissures representing the lode in the extreme western part of

[1] Lindgren, W., and Ransome, F. L., "Geology and Gold Deposits of the Cripple Creek District, Colorado," Prof. Paper U. S. Geol. Survey No. 54, 1906, p. 489.

[2] See Prof. Paper U. S. Geol. Survey No. 62. In press.

the mine are so feeble that they die out and are lost in the presence of minor cross-fractures.

The country rock throughout the mine is a fine-grained, somewhat sericitic quartzite which has been named the Burke formation.

The mine is worked through two long adits, the Campbell tunnel (east or Standard adit) and the No. 6 tunnel (west or Mammoth adit), run in a northerly direction into a steep hillside from two points on Canyon Creek. Above these adits are tunnels connecting with old workings; below them are the modern workings reached through a winze at the end of the Campbell tunnel.

The Standard fault strikes northwest and dips northeast at angles ranging from 65° to 70°. It thus meets the lode obliquely so that the ore extends considerably farther east on each successively lower level. The fault has not been recognized at the surface, where the facts that it is entirely within the Burke formation and that the steep slopes above the mine are covered with soil and vegetation render it invisible. No. 4 and No. 5 tunnels of the old workings both follow the Standard fault for several hundred feet before they reach the vein. Exposures of it are also to be had at the eastern ends of the 450, 650 and 850 foot[1] levels as well as in the Banner crosscut driven in a northeast direction from the Campbell tunnel, and on the No. 6 level of the Mammoth workings. In the crosscut the fault is marked by about 5 inches of dark clay gouge on the foot wall, with from 10 to 12 feet of crushed and sheared quartzite in the hanging wall. The material is soft as a whole, but tightly seals the fissure and appears to be comparatively impervious to water. The quartz is generally sheared and slaty in the vicinity of the fault.

When an ore body is found to be cut off by a barren fissure filled with the soft product of trituration known as gouge the conclusion that the ore has been faulted is usually and, in many instances, correctly drawn. If the direction and extent of the fault movement can be ascertained, the continuation of the ore

[1] Distances or depths are measured below the Campbell tunnel.

can generally be found without difficulty. If these data are not available, right and left crosscuts are perhaps run on the far side of the fault and continued until the ore is found or the search is abandoned.

The relation of the Standard fault to the ore is such as to suggest at once that the lode is cut off by a younger fissure. This was the view taken by J. R. Finlay[1] and is the one generally accepted in the district. The Banner crosscut was driven on the hypothesis that the fault is normal and that the portion of the lode east of the fault would accordingly be offset to the south. Unfortunately the development east of the fault was not carried far enough either to prove or to discredit this interpretation. If the fault is really later than the ore, the problem of the recovery of the displaced portion of the pay shoot on the northeast side of the dislocation is well worthy of attention. As the ore is generally wider near the fissure than anywhere else in the mine, there ought to be, somewhere just northeast of the fault, an ore body of such size that there would be no danger of crosscutting through it unaware. It is true that there is little clew to the amount and direction of the throw of the fault, owing to the homogeneous character of the rocks traversed; but the fact that the fault has not been recognized as a factor in the general geological structure of the district would indicate that it has not a very great displacement, although this might easily amount to several hundred feet and still escape detection in geological mapping at this particular place. If an approximately vertical throw be postulated, the offsetting of a lode so nearly vertical as the Standard-Mammoth should not be very great. On the supposition of a horizontal throw, or heave, the facts that the Standard-Mammoth lode is in line with the Hecla lode east of the fault and that it is obviously in the same general zone of fissures which contains both the Hecla and the Tiger-Poorman lodes are rather opposed to the idea of great displacement. In short, if the fissures represent a fault subsequent to ore deposition the conditions are favorable for the recovery of the eastern part

[1] "The Mining Industry of the Cœur d'Alenes, Idaho," *Trans. Am. Inst. Min. Eng.*, Vol. 33, 1903, p. 247.

of the lode. There is good reason, however, for questioning the opinion that the dislocation is in the main later than the ore.

As a rule, fault fissures once initiated, particularly if they are filled with gouge rather than with quartz or other solid vein material, continue to be planes of movement for long periods. Accordingly if an ore-filled fissure ends against a gouge-filled fissure of the same or greater age, the latter may and usually does show some displacement which is clearly later than the ore. In such a case the determination of the relative age of the ore and the cross fissure may offer some difficulty, and it is advisable before discussing the phenomena in the Cœur d' Alene district to consider the criteria that may be useful in determining whether a given fissure dislocates the ore or is anterior to ore deposition.

If the ore-bearing fissures is older than the fault its primary structural features should be independent of the latter. If the ore is banded, for example, the bands should be cut off sharply at the postdepositional fault. Usually there will be fragments of ore in the crushed material between the walls of the disturbing fissure. On the other hand, if the fault is older than the ore-bearing fissure the latter is likely to exhibit some characteristic change in the vicinity of the cross fracture. It may split up into smaller fissures, it may be wider here than elsewhere, or it may possibly, in some rare instances, be narrower. If the ore is banded the bands will turn across the lode and join at its end or they will merge into a massive structure. Although the ore at the cross fissure may be slickensided by later movement, it will not as a rule be sufficiently broken up to be dragged into the fault.

In practice these criteria are not always available. It is conceivable that in a lode formed mainly by replacement of the wall rock the ore may exhibit a banding which will be truncated at the fault even when the latter is anterior. The fault may be later than the ore and yet contain no visible crushed or dragged ore, or it may have originally antedated the ore and yet in consequence of vigorous later movement exhibit every appearance

of being a postdepositional fault, although of course there is no continuation of the lode beyond it.

The fact that one fissure may contain ore and another hold only a soft mass of claylike gouge is not in itself proof that the barren fissure is younger. A gouge-filled fissure appears to be distinctly unfavorable to ore deposition, probably in part because the gouge chokes the fissure and prevents the access of mineral-bearing solutions and in part because the movement along such a fissure is so nearly continuous as to give no chance for the deliberate and undisturbed chemical action which seems requisite for the formation of large, clean bodies of ore.

Examination of the Standard-Mammoth lode in the vicinity of the Standard fault failed to yield entirely decisive evidence as to the relative age of ore and fault. That some movement has taken place along the fissure since the ore was deposited is plain. On the other hand, the lode presents certain features which suggest that the fault was anterior to mineralization. The lode is generally widest and richest near the fault and on the lower levels divides into two branches just before reaching the fissure. Both of these facts are what might be expected on the supposition that the Standard fault is older than the lode. It is unlikely, on the other hand, that a fault having a decided inclination from the vertical would cut the lode so as to coincide on practically all levels with the widest and richest part of the ore shoot. The banding of the Standard-Mammoth lode, parallel to its walls, is not very distinct. So much of this structure, however, as was visible at the time of visit seemed not to be sharply cut off at the Standard fault, but to become less distinct or to show some tendency to curve and meet across the end of the lode. So far as known, no drag ore has yet been found in the Standard fault. These facts, and the failure to find beyond the fault the continuation of an ore body having such width immediately to the west of it, strongly suggests, if they do not prove, that the Standard fault is older than the Standard-Mammoth lode.

The Helena-Frisco mine, situated a short distance southwest of the Standard-Mammoth, contains three veins which are ap-

parently parts of a once continuous lode displaced by cross faults. The difficulties in the way of this view, however, are the diverse characters of the three veins and the lack of evidence for the existence of cross faults of sufficient magnitude to effect so great a horizontal displacement of the supposedly older fissures. The apparent cross faults are fissures which were probably formed before or contemporaneously with the opening of the lode fissures. This hypothesis could not be verified in 1904, owing to the inaccessible condition of many of the levels. The mine has since been reopened and it is possible that future observations may throw some light on the relations of the Gem, Frisco, and Black Bear veins.

In conclusion it is suggested that the softness of the clayey material known as gouge is not proof of recent origin but that, on the contrary, gouge-filled fissures may be very persistent and may retain their characteristic features long after neighboring fractures have been filled with solid ore. The gouge, by acting as a chemically inert lubricant, tends to localize rock movements in the fissure which it fills and thus by undergoing continuous slow squeezing to perpetuate its own existence. The extent to which this thesis is true, the criteria for the recognition of gouge-filled fissures older than associated ore-filled fissures and the physical and chemical behavior of gouge seams with reference to ore-bearing solutions, are questions upon which it is hoped some light may be shed by discussion in these pages and by the recording of additional observations by other observers.

F. L. RANSOME.

SECONDARY ENRICHMENT AND IMPOVERISHMENT.

Sir:—In your proposed discussion of the "Localization of values in Ore-bodies" in veins, it is probable that the secondary rearrangement, enrichment and impoverishment will be considered to be of paramount importance, especially in regard to to economic value of mineral deposits.

I, therefore, send you a few instances of such secondary action which may be of interest in this connection. All occur in the mining district of Leadville, Colorado.

The first sketch (Fig. 26) represents a longitudinal section along the course of the "Maid of Erin" ore-shoot, which has been continuously developed for a length of one and a half miles across several faults and which has a width of from 20 to 200 feet, with a thickness of ore of from 20 to 200 feet. This great thickness is made up of several layers of ore, one below the other, with barren country between the layers.

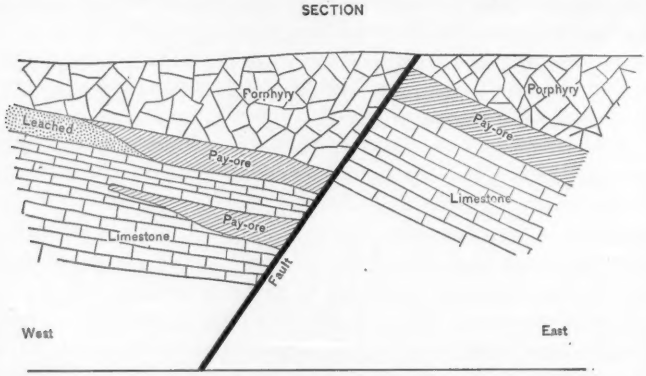


FIG. 26. Showing one ore-body broken by fault and existing on both sides of the fault-plane and a lower shoot, due to secondary action on one side of the fault only.

The ore lies on top of, and within, a body of limestone, capped by a mass of quartz-porphyry. The vein is nearly flat, with a dip of but 15 degrees from the horizon.

All the developments in the district prove that the faulting occurred after the formation of the ore-bodies.

The sketch speaks for itself. The upper layer of ore is continuous across the fault and displaced about 300 feet vertically. Its westerly portion is leached and contains but little value. The lower layer of ore does not exist east of the fault, drifts and diamond-drill holes in the proper places having failed to find it.

This proves that the lower layer of ore is secondary and a result of the leaching of a portion of the upper layer of ore.

This secondary layer of ore has a length of 600 feet with a thickness of 20 feet in places.

As a rule the migration of values is confined to a path within the main vein-crevice, but, in this instance, the values have been redeposited along the bedding-planes of the limestone at a horizon 100 feet and more below that of the original ore-body.

The second sketch (Fig. 27) illustrates in plan another interesting occurrence of rearrangement in a different portion of the same great ore-shoot.

The shoot in this vicinity is at least 200 feet wide and 20 feet thick. The dip of the vein is to the east at an angle of 15 degrees. The upper portion on the west is entirely oxidized

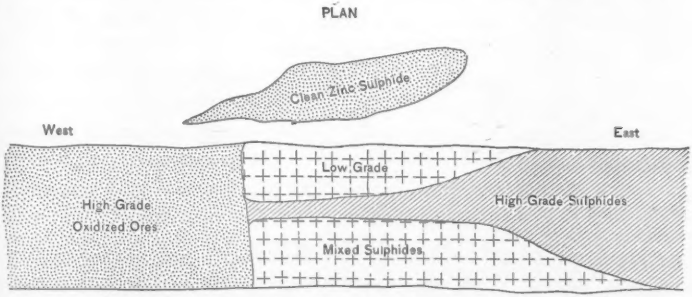


FIG. 27. Illustrates relation of oxidized to unoxidized ores and relation of high and low grade areas in Maid of Erin shoot, Leadville, Colorado.

and consists of carbonate of lead and iron oxide, containing silver. The change to sulphide is not gradual, but sudden along the line indicated in the sketch. The ore at this line of change contains a great deal of native silver and the zinc, originally contained in the ore-body, is entirely leached out, the oxidized ores containing less than one per cent. of that metal.

The long face of sulphide exposed in the workings, after the oxidized ores had been stoped out, showed a nearly homogeneous mixture of lead, zinc and iron sulphides, low in silver. Its value was too low for profitable mining and the ore was left standing for quite a while, until repeated and more careful sampling of the entire face indicated that the central 20 feet contained more lead and silver than the remaining 180 feet.

A drift was started at this point and it was found that the richer channel continued to the east, gradually widening until it occupied the entire width of the shoot. This higher grade of ore carried more lead and silver than the adjoining low grade bodies, but contained the same amount of zinc.

Later, a large body of zinc ore, carrying from 30 to 40 per cent. of that metal, was found to the north of the main shoot, as shown on the sketch.

The fact that the richer sulphide core of the main shoot contained the same amount of zinc per ton throughout, as the adjoining low-grade portions and the existence of the body of clean zinc ore, seem to demonstrate that both phenomena were the result of secondary rearrangement.

Both instances illustrate that the values leached from ore-bodies by surface waters, will be found redeposited below and that, sometimes, it is wise to prospect for lost values outside of the main channel.

A third instance is found in the same district, but in a different ore-shoot.

Here the rocks had been eroded down to the ore-bodies in certain places. The ores were oxidized thoroughly. In one particular locality the ore-body had been eroded entirely, but here the loose, overlying wash was plastered with silver chlorides for a distance of 10 feet above the rock in place. Several hundred tons of this loose rock, containing from 40 to 60 ounces of silver per ton, were shipped from this vicinity. This occurred at a depth of 150 feet below the surface.

MAX BOEHMER.

DENVER COLORADO.

THE ORE DEPOSITS OF COPPEROPOLIS, CALIFORNIA.

DISCUSSION OF PAPER BY JOHN A. REID.

Sir: In the issue of ECONOMIC GEOLOGY for December, 1907, Mr. H. W. Turner has contributed a discussion on my paper dealing with the Copperopolis ore deposits. In this discussion he appears indirectly to accuse me of having slighted the results

of his own work in the Sierra Nevada. I wish to state that nothing was further from my thoughts, and I regret exceedingly to have laid myself open to such interpretation. I fully appreciate the great value of the work of both Mr. Turner and Mr. Lindgren, and I am very sorry that their labors in the Sierra have ceased. I noted the fact that in the papers referred to hornblendite had not been given an individual place as a distinct species. This I did as I wished to emphasize the fact that I regard the Copperopolis rocks as originally amphibolitic and worthy of recognition as such. I have been able thus far to detect no pyroxene, although further search may reveal this mineral. The porphyritic facies of the hornblendite shows large idiomorphic hornblendes, in a finer-grained matrix of the same constituent with a little basic feldspar. There is no suggestion of derivation from pyroxene. At the same time I would class the hornblende rock with the family of the pyroxenites because in the Sierra Nevada the latter represent the prevailing mode of crystallization of the various similar ultrabasic intrusives. I have come to look upon the hornblende-bearing rocks as having crystallized from magmas containing more water than those from which the pyroxenic rocks have resulted. I expect to be able to substantiate this belief in the future, particularly as the question bears distinctly upon the formation of ore deposits.

Mr. Turner's criticism of my ascribing the copper ore to the hornblendite is apparently a just one. It is obviously unscientific to connect the ore genetically with the upper portion of the basic intrusive, as the latter is in small volume. This brings into the discussion a new line of inquiry, and a brief consideration of the recent paper of Mr. Spurr, "A Theory of Ore-deposition." It has been forced upon my attention for some time that we cannot connect in many instances certain ore deposits with definite masses of igneous rocks, even though we may be sure from all the evidence that *some* genetic relationship holds. At Copperopolis the fresh hornblendite is copper-bearing, but the ore certainly did not come from the intrusive rock exposed in the mines. It must have come from the basic

magmas below, the product of a deep differentiation. I think I used the phrase *genetically connected with,* in writing of this matter in my paper. Such a phrase is sufficiently elastic to cover our expanding knowledge of ore deposits. I believe that it ill befits the youngest members of the profession to put forth new theories; that work should be left to the older men. I agree with Mr. Spurr in part; in part I do not. I have seen comparatively too many instances of ore differentiation from the upper portions of intrusive magmas to allow me to adopt the idea of a predominant differentiation at great depth. I believe that the structural conditions, or better, the conditions of crustal stress at times of igneous intrusions play a great part in magmatic differentiation of ores and must be considered in a working theory of ore deposition. At Copperopolis the copper ore, and hornblendite illustrate deep differentiation; the granodiorite, with its original pyrite, is an example of differentiation in the upper portions of igneous intrusions. Both are true conditions, and we should not push either one too far.

In closing I can state that the paper on Copperopolis I hope to make but the beginning of further and more detailed studies of the copper belt. There is much to be done, for the field is almost untouched.

JOHN A. REID.

TRIUNFO, BAJA CALIFORNIA, MEXICO,
April 7, 1908.

REVIEWS

Mineral Resources of the United States for the Calendar Year 1906. Pp. 1307. Washington, 1907, U. S. Geological Survey.

This is the twenty-third annual volume of the series begun in 1883, "Mineral Resources of the United States," published by the United States Geological Survey. The object of this series of reports when begun in 1883, as now, was, as stated in the introduction to the twenty-second volume (1905), to present a statement of the known mineral resources of the United States and a statistical statement of the production of these materials and the uses to which they were applied. Prior to 1883, the government's official information of the production of various mineral resources was limited to the statement in the census reports and to occasional fragmentary studies of special mineral products.

Like the twenty-two preceding volumes of the series, this volume contains a statement of the production of mineral substances in the United States during 1906, and, in addition, it records the chief features of mining progress during the year. As stated in the introduction, practically the same form of arrangement has been preserved in all of the twenty-two preceding volumes of this series. The volume is divided into chapters, each of which treats of a separate mining industry for the entire United States. The statistics are not grouped by states but the mineral resources of each state are given in a tabular statement of output by states in the summary (pages 46 to 65) and in the index (pages 1277 to 1307), in which, under each state, is a list of the mineral products therein. An important feature of the recent volumes of the series is a summary statement of "conditions of the domestic industry in relation to foreign conditions in the same mineral industry."

To those unfamiliar with the volumes of "Mineral Resources" it is important "to know that this volume is simply the consolidation of the separate chapters after they have been published in pamphlet form, frequently months in advance, and that these pamphlet reports and not the final volume mark the dates at which the reviews become available. Further, for greater statistical promptness, the principal figures are given to the public press in advance even of the publication of the chapters in pamphlet form."

Considerable importance attaches to the present volume in that it marks the change of policy announced in the preceding volume for 1905 "of assigning all subjects to members of the Survey staff, who in this work and in allied problems are employed solely in the government service." As a result of this change several new names appear in this volume as the responsible authorities in charge of individual chapters. I quote the several paragraphs of the introduction relating to this change. These are:

"The report on iron ores for 1906 was prepared by Mr. Edwin C. Eckel, who in past years has made a special study of the iron ores of the South. The series of iron-ore reports for the United States, however, owes its statistical development entirely to Mr. John Birkinbine, of Philadelphia, . . . Under his direction the statistics of iron-ore production have been developed to an exceptionally high degree of accuracy. This has been due . . . fundamentally to the great confidence given him by iron-ore producers, among whom Mr. Birkinbine has developed a spirit of fraternity similar to that which Mr. James M. Swank, the general manager of the American Iron and Steel Association, has evoked among the iron and steel manufacturers."

"The reviews of the copper, lead, and zinc trades in preceding years have likewise been developed entirely by Mr. Charles Kirchhoff, of the Iron Age, New York. These reports have become classic for their statistical accuracy and for their keen and fair analysis of the trade situation." The report on copper for 1906 was made by Mr. L. C. Graton, and those on lead and zinc by Mr. J. M. Boutwell.

"This volume also records the change of the administrative head of the Division of Mining and Mineral Resources from Dr. David T. Day to Mr. Edward W. Parker . . ." Dr. Day will devote his time to the very important work of preparing the reports on petroleum and natural gas.

"The change of administration includes the placing of the statistics of metal production (except iron ores) under the supervision of Mr. Waldemar Lindgren, who has as chief assistants Mr. Chas. G. Yale, of San Francisco; Mr. Victor C. Heikes, of Salt Lake City; Mr. Chester Naramore, of Denver, and Messrs. Boutwell, Graton, McCaskey, and Siebenthal, of Washington. This arrangement has materially strengthened the work of the division."

The standard of accuracy and completeness, and the uniformity in method of presentation, attained in this series of reports (including the statistics of imports and exports of minerals, which form an essential part of the volume), under the able direction of the former chief, Dr. David T. Day, have been due, in very large measure, to two principal facts, namely, (1) in securing the coöperation of those who were recognized as the best experts for each of the mineral industries, and resting the entire responsibility for the subject treated with the individual appointed as special agent with authority to conduct correspondence relating thereto and to accept confidential information in the name of the government; and (2) to the continuing in charge the various experts, some of whom remained in charge of their assigned subjects for more than twenty years—"indeed, from the beginning of the series until the present time . . ." Under the present plan of reorganization, however, the Division of Mining and Mineral Resources is made an integral part of the Geologic Branch of the Survey, and under this plan of coöperation the value of future volumes of "Mineral Resources" will be increased by supplementing the statistical data with the results of geological and chemical research, in so far as these pertain to the economic development of the mineral resources. Moreover, in carrying out this plan of coöperation with the Geologic Branch of the Survey, a twofold advantage is secured. "It brings to

the statistical work, on the one hand, a corps of trained men whose field observations have developed a keen appreciation of the geologic and economic importance of each mineral product," especially shown in the reports made by Mr. Waldemar Lindgren and assistants on gold and silver in the volume for 1905, and in reports on the same and other subjects in the present volume. "On the other hand, the mining geologists have obtained and will continue to derive from their statistical work an insight into the industrial and commercial conditions which so largely affect the demand for the different minerals and lead to the search for and the development of the mineral deposits with the geological relations of which their field work makes them acquainted."

"The bringing together of these two classes of study of our mineral resources, that of their geology and manner of occurrence and that of their statistics and economic conditions, is to be one of the special features of the future work" of the Division of Mining and Mineral Resources.

During the twenty-seven years covered by the twenty-three reports of this series the scope of the work has remained essentially the same, but the work involved has increased in two directions. "In the beginning the statistical feature of the work was satisfied by an estimate as to the total output of each useful mineral. This estimate was based upon the best commercial estimates available, and the statistical correspondence was limited to a few hundred letters each year. When the control of the work passed into the hands of Doctor Day, he took it with the intention of developing each statistical inquiry from an estimate into an accurate annual census as rapidly as facilities would permit. This result has now been achieved with every industry except petroleum, and to this particular and difficult task he will henceforth limit his work. The correspondence necessary for this annual census of the mines of the United States has grown from a few hundred letters a year to an average of three written or printed communications a year to every known mine operator of the United States—more than 150,000 in all. In order to make such correspondence successful,

it has been necessary to send agents to the mines themselves, both for scrutiny of the statistical returns and in order to acquaint the operator with the nature of this inquiry, and thus to secure the coöperation essential to success."

The mineral production of the United States has increased more than fivefold from 1880 to 1906, inclusive. "From $364,928,298 in 1880 the value rose to $451,000,000 in 1882, declined to $406,000,000 in 1884, rose steadily to $606,000,000 in 1890, declined slightly to $605,000,000 in 1891, rose to $622,000,000 in 1892, fell to less than $550,000,000 in 1893 and 1894, rose to $640,000,000 in 1895, remained at the same figure in 1896, rose rapidly to $1,491,000,000 in 1903, declined to $1,361,000,000 in 1904, rose to $1,623,000,000 in 1905, and advanced to the immense sum of $1,902,517,565 in 1906."

THOMAS L. WATSON.

UNIVERSITY OF VIRGINIA.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

CHARLES H. CLAPP.

METALLIFEROUS DEPOSITS.

COPPER.

The Copper and Tin Deposits of Katanga (Congo Free State). By J. R. FARRELL. Eng. and Min. Journ. April 11, 1908. Pp. 747–753, with 2 maps and 9 photos.

Kansanshi Mine (Rhodesia) and Mine Sampling. By J. R. FARRELL. Min. and Sci. Press. April 18, 1908. Pp. 528–530, a map and 2 photos.

Foothill Copper Belt of the Sierra Nevada. By J. A. REID. Min. and Sci. Press. March 21, 1908. Pp. 388–393, with outline map, 2 figs., and 2 photos.

The Great Fitzroy Copper and Gold Mine, Mt. Chalmers, Rockhampton District. By B. DUNSTAN. Queensland Geol. Sur. Bull. No. 216, 1907. 58 pp.

Cloncurry Copper Mining District. By L. C. BALL. Queens. Gov. Min. Journ. Feb., 1908. 10 pp. (Conclusion of a long article, running continuously since Sept., 1907.)

Das Kupferschieferlager in Anhalt. By O. V. LINSTOW. Zeit. f. prakt. Geol. Pp. 56–62; with a sketch map.

Kupfervorkommen in Kalifornien und ihre wirtschaftliche Bedeutung. By W. A. LIEBENAM. Zeit. f. d. Berg-Hutten- u. Salinen-Wesen. Vol. 55, No. 4, 1907. Pp. 522–546, with 3 figs., 2 maps and a geol. map.

GOLD.

Rawhide, Nevada. By A. D. MAR. Eng. and Min. Journ. April 25, 1908. Pp. 853–854, with a map and a photograph.

The Geology of Stateline District, Utah. S. L. Min. Rev. Mar. 15, 1908. 2½ pp.

The Mangana Goldfield. By W. H. TWELVETREES. Geol. Sur. of Tasmania Bull. No. 1. 1907. 36 pp., with 3 maps.

The Geology and Mineral Resources of Lawlers, Sir Samuel and Darlot (East Murchison Goldfield), Mount Ida (North Coolgardie Goldfield and a portion of the Mount Margret Goldfield. By C. G. GIBSON. Geol. Surv. West Australia, Bull. 28. 1907. 73 pp., with 4 figs., 3 maps and 5 ground plans.

A Report Upon the Geology together with a Description of the Productive Mines of the Cue and Day Dawn Districts. By H. P. WOODWARD. Western Australia Geol. Surv., Bull. No. 29. 1907. 141 pp.

IRON.

Iron Mining in Cuba. The Iron Age. April 9, 1908. Pp. 1149–1157, with a map and 11 photos.

The Magnetite Belts of Putnam County, N. Y. By C. A. STEWART. Sch. of Mines Quart. April, 1908. Pp. 283–294, with a map and 4 figs.

LEAD.

Das Emser Blei- und Silberwerk, unter besonderer Berücksichtigung der in den letzten Jahren geschaffenen Neuanglagen. By H. L. LINKENBACH. Glückauf. Vol. 44, 1908. Pp. 368–375, 405–414, with 22 figs. and a map, scale 1:20,000.

MANGANESE.

Das Manganerzvorkommen in der Nähe von Ciudad Real in Spanien. By R. MICHAEL. Zeit. f. prakt. Geol. March, 1908. Pp. 129–130.

MOLYBDENUM.

Molybdenum Ore in the United States. By F. G. HESS. Advanced chapter U. S. Geol. Survey Bull. 340, Part 1, Contributions to Economic Geology, 1907.

RARE METALS.

Occurrence and Uses of Tantalum. Bull. Imp. Inst. Vol. V, No. 4, 1907. 9 pp.

SILVER.

Promontorio Silver Mine, Durango, Mexico. By F. C. LINCOLN. Eng. and Min. Journ. April 11, 1908. Pp. 756–759, with a sketch map and two photos.

TIN.

Notes on Tin Mining in Cape Colony. By H. D. GRIFFITHS. Jl. Chem., Met. and Min. Soc. of S. Africa. Dec., 1907. Pp. 167–181, 7 figs. and 4 photos.

Northern Tin Fields of Bolivia. By C. PREUMONT. The Min. Journ., London, Vol. LXXXIII., 1908. Pp. 160, 249 and 314.

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CEMENT.

Concrete Materials in the Chicago District. By E. F. BURCHARD. Advanced chapter from U. S. Geol. Survey Bull. 340, Part 1, Contributions to Economic Geology, 1907.

CLAY.

Uber Kaolinbildung. By H. STREMME. Zeit f. prak. Geol. March, 1908. Pp. 122–128.

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The Arkansas coal field. By A. J. COLLIER. With reports on the paleontology, by DAVID WHITE and G. H. GIRTY. U. S. Geol. Survey Bull. No. 326. 1908. 158 pp. and 4 photos.

The Future Supply of Anthracite Coal. By R. LEE. Coal Mining Supplement of the Eng. and Min. Journ. March, 1908. Pp. 5–10, with 4 maps and 2 figs.

Classification of Coals by the Split Volatile Ratio. By D. B. DOWLING. Can. Min. Journ. April 15, 1908. Pp. 143–146, with 3 diagrams.

The Brown Coal Deposits of Victoria. By R. A. F. MURRAY. Aust. Min. Stand. Jan. 22, 1908. ¾ p.

Uber die Möglichkeit der Aufschliessung neuer Steinkohlenfelder im erzgebergischen Becken. By C. GABERT. Zeit. f. prakt. Geol. March 1908. Pp. 114–119, with a map.

Lage des Steinkohlenbergbaus in Frankreich. By E. REUMAUX. Stahl und Eisen. No. 28, 1908. Pp. 342–344.

Sur la Structure du Basin houiller du couchant de Mons. By J. CORNET. Ann. de la Soc. Geol. de Belgique. Nov. 15, 1907. 7 pp.

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Gas Fields of the Bighorn Basin, Wyoming. By C. W. WASHBURNE. Advanced chapter. U. S. Geol. Survey Bull. 340, Part 1, Contributions to Economic Geology, 1907.

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Diamonds in Arkansas. By G. F. KUNZ and H. S. WASHINGTON. Bull. No. 20, A. I. M. E. March, 1908. Pp. 188–194.

The Kimberlite Rock and the Origin of Diamonds. By F. W. VOIT. The Mining Journ., London. Feb. 22, 1908. Pp. 219–220. (Paper read before the Geological Society of South Africa.)

SALTS.

Zur Geologie der deutschen Zechsteinsalze. By H. EVERDING. Festschrift zum X. Allgemeinen Bergmannstage in Eisenprofiles. Berlin, 1907. (Kgl. Geolog. Landesanst.) (Abstract in Geol. Centralb., March 15, 1908, pp. 682–687.)

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Summary of the Controlling Factors of Artesian Flows. By M. L. FULLER. U. S. Geol. Surv. Bull. No. 319. 1908. 42 pp., 7 plates.

Geology and Water Resources of a Portion of the Missouri River Valley in northeastern Nebraska. By G. E. CONDRA. U. S. Geol. Surv. Water Supply Paper, No. 215. 1908. 130 pp., 20 plates.

Water Resources of Beaver Valley, Utah. By W. T. LEE. U. S. Geol. Surv. Water Supply Paper, No. 217. 1908. 57 pp., 1 plate.

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REGIONAL REPORTS.

Growth and Decay of the Mexican Plateau. By R. T. HILL. Eng. and Min. Journ. April 4, 1908. Pp. 681–688, with 12 photos.

The Mining Possibilities of the Department of Cuzco, Peru. By E. J. DUENAS. The Mining Jour. London. Vol. LXXXIII. Pp. 284, 315–316. Abstracts from Bol. del Cuerpo de Ing. de Minas del Peru. No. 53. Lima, 1907. 194 pp., with two maps and views.

Geologic Reconnaissance in the Matanuska and Talkeetna Basins. By S. PAIGE and A. KNOPF. U. S. Geol Survey Bull. No. 327. 71 pp., and 4 plates.

The Elk Point (Nebraska—South Dakota—Iowa) folio. By J. E. TODD. U. S. Geol. Survey folio No. 156. 7 folio pp. of text and 3 maps.

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The Geology of the District about Haenertsburg, Leydsdorp, and the Murchison Range. By E. T. MELLOR. Ann. Rept. Geol. Survey, Transvaal Mines Dept. Pretoria, 1907. Pp. 21–52, figs. 1–4. Plates IV.–VII., XXI.–XXII., map XXXII.

The Geology of the Central Portion of the Middleburg. By E. T. MELLOR. Ann. Rept. Geol. Survey Transvaal Rep. of Mines. Pretoria, 1907. Pp. 53–71, figs. 5–6, Plates VII.–IX., XII.–XXIV., XXXIII.

The Geology of the Central Portion of the Lydenburg District between Lydenburg and Belvedere. By A. L. HALL. Ann. Rept. Geol. Survey, Transvaal Mines Dept. Pretoria, 1907. Pp. 73–100, plates X.–XVII., XXV., XXX., XXXIV.

The Geology of the Coromandel Subdivision, Hauraki, Auckland. By C. FRAZER. New Zeal. Geol. Survey Bull. No. 4. 1907. 154 pp.

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Preliminary Report on the Geology of the Eastern Desert of Egypt between lat. 22° N. and 25° N. By W. F. HUME. Egyptian Survey Dep. Paper No. 1. 1907. 72 pp., with 5 plates and 4 maps.

Die Nutzbaren Minerallagerstätten Dalmatiens. By R. SCHUBERT. Zeit. f. prakt. Geol. Feb. 1908. Pp. 49–56, with a map.

Die Nord schwedischen Eisenerzlagerstätten. By R. BARTLING. Zeit. f. prakt. Geol. March, 1908. Pp. 89–108, with a map.

Der Erzbergbau in Steiermark, Käruten und Kram. By DR. AHLBURG. Zeit. f. d. Berg-Hutten. U. Salinen-Wesen. Vol. 55, No. 4. 1907. Pp. 463–521, with 28 figs. and a geol. map, scale 1:1,500,000.

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Artificial Vein Formation. By R. C. CANBY. Eng. and Min. Journ. April 4, 1908. P. 719.

Versuche über das Eindringen schmelzflüssiger Metalsulfide in Silikatgesteine. By O. STUTZER. Zeit. f. prakt. Geol. March, 1908. Pp. 119–122.

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A Tertiary River Channel near Carson City Nevada. By J. A. REID. Min. and Sci. Press. April 18, 1908. Pp. 522–525, map, profile, and 6 photos.

The Data of Geochemistry. By F. W. CLARKE. U. S. Geol. Survey. Bull. No. 330. 1908. 716 pp.

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SCIENTIFIC NOTES AND NEWS[1]

MINING AND METALLURGICAL SOCIETY OF AMERICA.

At a meeting held April 20, 1908, a constitution and by-laws were adopted by the recently organized Mining and Metallurgical Society of America. The full text of this constitution and by-laws is given on page 354.

A letter recently issued by Mr. J. R. Finlay, secretary of the Council, epitomizes the essential features of this document. The following is extracted from it. The italics are our own:

"Officers for the first year are to be elected at the next meeting of the Council, on May 18th, and in the meantime, Professor H. S. Munroe is acting as Chairman, and J. R. Finlay as Secretary of the Council. The routine work of correspondence is being looked after by Edward K. Judd, in care of Mr. Finlay, Room 1310, No. 2 Rector St., New York.

"The new Society will endeavor not to duplicate any of the work which is now being admirably performed by the American Institute. It will aim, on the contrary, to perform certain functions which the older organization is forbidden, by its Constitution and established policy, to undertake. The distinguishing features of the new Society will be these: *Enforcement of more stringent qualifications upon membership; subdivision into local branches; frequent meetings of an emphasized social character; discussion of subjects of public concern, as well as of professional interest; and the promulgation of authoritative opinions on such subjects.*

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

"In regard to this last mentioned function, the Constitution and By-Laws have been framed so as to permit the greatest freedom of discussion, without committing the Society, as a whole, to an expression of opinion until a preponderating number of the members have registered their views on one side.

"Social activity is to be stimulated by means of a simple dinner, or smoker, preceding each meeting. Local meetings will, so far as possible, be held simultaneously, and an itinerant member of one section will, of course, be welcomed at the meetings of any and all sections."

The constitution and by-laws as submitted to the meeting held on April 20, 1908, are given in detail below.

CONSTITUTION.

1. The name of the association shall be Mining and Metallurgical Society of America.

2. The association shall have for its objects the conservation of mineral resources, the advancement of mining and metallurgical industries, the better protection of mine investors and mine workers, the increase of scientific knowledge, and the encouragement of high professional ideals.

3. The society shall comprise Honorary Members and Members who must be qualified by knowledge, experience, and honorable standing to advance the objects of the association, and shall be proposed for and elected to membership as provided in the by-laws of the society.

4. All interests in the property of the society of persons resigning, or otherwise ceasing to be members, shall vest in the society. No member or officer shall receive salary, compensation, or emolument unless authorized by the by-laws, or by concurring vote of two-thirds of the executive council. Members residing for a year or more beyond the limits of the United States, Canada, and Mexico, shall not be entitled to vote nor hold office during the period of such residence.

5. The affairs of the association subject to the provisions of the constitution and by-laws shall be managed by an executive council of not less than fifteen managers, who shall hold office for the prescribed term or terms, and who shall elect from their own number, a President, not less than four Vice-Presidents, a Secretary and a Treasurer, who shall hold office for one year, or until the close of the meeting at which their successors in office are elected, and who shall be eligible for re-election. Additional officers may be elected by the executive council from time to time if necessary for the purposes of the association.

6. The annual meeting of the association shall be held on the second Tuesday in January of each year. One-third of the members, present in person or by proxy, shall constitute a quorum for the transaction of business.

7. The association may adopt by-laws, rules and regulations for the conduct of its business provided that these are in harmony with this constitution, and may provide different methods for amending or repealing such by-laws, rules and regulations.

8. Amendments to the constitution may be presented at a regular or business meeting of the association; and if endorsed by the council or in writing signed by at least twenty members, a copy of such proposed amendment shall be sent to all entitled to vote, accompanied by comment by the council if it so elects, at least thirty days in advance of a second meeting called for its consideration; at which meeting the amendment may be amended as to wording but not as to intent, and then shall be submitted to a final vote by sealed letter ballot sent to all members; the polls shall be open for sixty days, and for the adoption of the amendment a majority of those entitled to vote shall be required to have been recorded in the affirmative; provided, however, that a negative vote comprising a majority of the votes cast shall defeat the amendment. If the necessary vote for adoption or for rejection is not secured on the first ballot, the council shall order the sending of a second ballot by registered mail to members who have not recorded their vote; and in such case, so many of these second ballots as have been received by members, if not voted within a further period of sixty days, shall be counted as votes cast in the affirmative. The ballots shall be voted, canvassed and announced as provided in the by-laws.

BY-LAWS.

1. A candidate for membership shall submit in such form and in such detail as may be prescribed in the rules and regulations of the council a statement of his professional experience. The candidate must have had eight years' practical or professional experience, including not less than five years in positions of responsibility, in mining or allied lines of work. Graduates of approved engineering schools shall be credited with one-half the time prescribed for graduation. The candidate must be endorsed by three or more members who shall further certify as to his qualifications for membership in writing. These statements must be based on long or intimate personal knowledge, and shall be submitted in such manner as the council may direct. The candidates must be approved by the council, and elected by sealed letter ballot, sent to all members of the association entitled to vote. Adverse votes, received within sixty days, amounting to five per cent. of the votes cast, shall

be required to defeat the candidate. A candidate may renew his application a year or more after his rejection.

2. Honorary Members, not to exceed ten in number, must be proposed in writing, setting forth at length the qualifications of the candidate, and signed by at least twenty members of the association. The candidate must be elected by vote of the council which shall be by sealed letter ballot. One dissenting vote shall defeat such election. Honorary members are not entitled to vote nor to hold office and shall not be required to pay initiation fees nor annual dues.

3. All elected candidates shall be duly notified and shall subscribe to the constitution and by-laws in such form as the council may direct. This latter provision shall not apply to Honorary Members.

4. There shall be an initiation fee of twenty-five dollars for each new member after the total membership reaches two hundred and fifty.

5. The annual dues shall be ten dollars, payable in advance in January of each year. The council may in its discretion permit any member not in arrears to become a life member on payment of an adequate sum for the purpose based on his expectation of life according to reliable tables of mortality.

6. The membership of any person in the association may be suspended or terminated for reasons of weight by a four-fifths vote of the executive council. Notice of such intended action shall be sent to such member by registered mail and action shall not be taken for at least thirty days after the receipt of this notice by such member. A member suspended or expelled may demand a sealed letter ballot sustaining the action of the council. This ballot shall be sent to all members entitled to vote and may be accompanied by a statement signed by the council or a committee thereof, and by a statement on behalf of the accused of not more than one thousand words, or not exceeding in length that prepared by or for the council. A majority of the votes received within thirty days shall be required to reverse the action of the council.

7. The executive council shall from time to time divide the territory occupied by the membership into fifteen geographical districts to be designated by numbers. Each of the districts shall be, as nearly as practicable, contiguous territory; each shall contain as nearly as practicable an equal number of members. The council shall announce such division to the association three months before the annual meeting. There shall be at any one time not more than fifteen managers, one from each district, whose term of office shall be so arranged that five of them shall retire each year.

8. Three months before the annual meeting the secretary shall send a nomination ballot to each member of the association in the districts for which new managers must be elected, with the request that he

shall nominate three members, in such manner as the council may direct, as candidates for manager to represent his district. Nominations shall be received for twenty days when the polls shall be closed. Sixty days before the annual meeting the secretary shall prepare a ballot, containing in and for each of these districts not less than three names, which shall be in each case those receiving the largest number of nominating votes before the closing of the polls. This ballot shall be mailed to each member entitled to vote, who may vote for one manager in each district, having the right to substitute names not on the list, and to cast not over three votes for a single candidate, provided that the total number of votes cast by such member shall not exceed the total number of vacancies to be filled. The ballot shall be signed, sealed and voted as prescribed in by-law 15.

9. At noon of the first day of the annual meeting the polls shall be closed and the ballots counted by tellers appointed by the President. Managers shall not be eligible for such appointment. The candidate in each district, receiving the largest number of votes shall be elected. In case of a tie the President shall cast the deciding vote.

10. The term of office of a manager shall begin immediately upon election. Vacancies occurring at any time in the council may be filled until the next annual election by a majority vote of the remaining members. At the next annual election new managers shall be elected to fill such vacancies for the unexpired term of office only.

11. The officers of the association, as provided in the constitution, shall be elected at the annual meeting, or whenever a vacancy occurs, by a majority vote of the council. Their term of office shall begin at the close of the meeting at which they are elected. For reasons of weight any office, except that of manager, may be declared vacant by a two-thirds vote of the council. The duties of the several officers shall be such as usually attach to the office or such as may be determined by the council. The council may delegate its powers to persons or committees, and may make such rules and regulations as may be necessary for the proper conduct of the business of the association, provided that these are in harmony with the constitution and by-laws.

12. Meetings of the council for the transaction of business may be called at any time by the President, and shall be called at the request in writing of three managers. Unless for reasons of weight at least ten days' notice of meetings shall be given. Five managers shall constitute a quorum. A letter ballot of the council shall be taken on any question of importance if so ordered by the presiding officer at any meeting, or at the request in writing of three managers.

13. The council shall provide for regular stated meetings of the Society for the transaction of business or for the reading or discussion of papers to be held at such times and places as may best serve the

interests of the association. Special meetings of the Society or of any section thereof, for a definite purpose, may be called by the President, or shall be called, on a request in writing signed by twenty members. It shall not be in order at a special meeting to discuss other business than that stated in the call for the meeting. Except for reasons of weight, at least thirty days' notice shall be given of all meetings. Except at annual meetings ten members present in person or by proxy shall constitute a quorum. Resolutions endorsing or condemning matters of public or professional interest shall take the course prescribed for amendments to the constitution. Other matters of importance, by vote of members present at any meeting, or by direction of the presiding officer, or by vote of the council, may take the same course.

14. Local sections or professional groups of members of the Society may be organized for social, scientific and professional purposes in harmony with the constitution and by-laws, and such sections shall have such powers, and shall act under such rules and regulations as the council may from time to time approve.

15. When sealed letter ballots are required by the constitution or by-laws, the envelope to contain the ballot shall be so designed that it may be signed on the outside by the voter for identification, and may afterwards be opened by the tellers so as to preserve the secrecy of the ballot. The endorsement may take the form of a proxy, to be voted by the tellers appointed by the President, or by such other person, not a manager, as the member may designate. The ballots signed and sealed shall be mailed or delivered to the secretary, who shall be responsible for their safe keeping, and who shall endorse thereon the date and time of receipt and make record of such receipt on a list of members kept for the purpose. Any member shall have the privilege at any time before the closing of the polls, of substituting another ballot, in which case the original shall be returned to him unopened. After the closing of the polls the ballots, arranged in alphabetical order, with the check list of members above mentioned, shall be delivered by the secretary to tellers appointed by the President. The tellers shall verify the check list, and open and mix thoroughly the votes in such manner as to preserve the secrecy of the ballot. The ballots after being counted by the tellers shall be destroyed, and the report of the tellers shall be the official record of the vote. In case a supplementary ballot shall be ordered for members failing to vote on the first ballot, the members whose votes have been counted shall not be permitted to vote a second time nor to change their original vote. The result of the ballot shall be communicated to the members of the association at such time and in such manner as the council shall determine, and shall be announced by the presiding officer at the next business meeting of the association, and recorded on the minutes.

16. The council shall by a two-fifths vote of its members, and upon request in writing of twenty per cent. of the members of the Society, make any important question submitted to the membership a vote of confidence. In case such question is decided against the council the members shall resign office, their resignations to take effect on the election of their successors, and a new election of the whole executive council shall be ordered to be conducted as provided in the by-laws. The new council shall by lot divide themselves into three classes to serve until the next annual meeting and for one and two years thereafter respectively.

17. Amendments to the by-laws shall take the course provided for amendments to the constitution, save that when the letter ballot is taken a majority of the votes received within thirty days shall pass or defeat such amendments.

There can be little doubt that with the aims above set forth, the new Society will fill a place in connection with mining engineering, metallurgy and geology which has heretofore received too slight emphasis in this country. It has for many years been a source of some chagrin to those engaged in professional mining and scientific work that there should be no organization in which membership alone would carry with it assurance of some measure of accomplishment and recognized standing in the professional world.

The evidence which the organizers of the new Association have given of lines along which the Society is expected to develop affords promise of the effective fulfillment of functions for many years entirely neglected.

A FUND AMOUNTING on March 1, 1907, to $30,500 contributed by nearly 800 Harvard alumni was given to the President and Fellows of Harvard College to commemorate the long services of Professor Nathaniel Southgate Shaler and the great affection in which he was held by his many students and friends. The use of the fund was left for the determination of a special committee, which decided first to set aside a sum for the erection of a memorial tablet in the Geological Section of the University Museum or elsewhere in Cambridge, and, secondly, to apply the income of the balance of the fund to the support of

research in the Division of Geology and in the publication of the results of such research. These researches are to be undertaken by persons nominated by the Committee of the Division of Geology and appointed by the corporation whether such persons are officers or students of Harvard University or not. The subject and locality or field of research are to be approved by the Division Committee and the allotments are also to be determined by this committee with the approval of the corporation. Any work or journey thus supported in whole or in part shall be carried on under the name "Shaler Memorial Research" or "Shaler Memorial Expedition."

The Division of Geology at Harvard includes the subjects of geology, economic geology, palæontology, physiography of the lands, meteorology, mineralogy and petrography. Researches in any one of these fields are within the scope of the Shaler Memorial fund.

The first research undertaken with the aid of the fund has assumed the form of an expedition to South America in charge of J. B. Woodworth, assistant professor of geology at Harvard University.

The chief object of visiting South America is to make a critical examination of the Permo-Carboniferous conglomerates of Brazil with reference to the agencies or agency concerned in their erosion, transportation, and deposition, with special reference to the question of Carboniferous glaciation. Professor Woodworth will spend the months of July, August and September at least in the southern highlands of Brazil in this quest, accompanied by Mr. Winthrop P. Haynes, assistant in geology at Harvard. The Division committee decided upon this field of investigation as peculiarly appropriate to the character of the memorial since the late Professor Shaler early and late taught that the Carboniferous was a glacial period. The Brazilian conglomerates are not at all unknown but there remains much to be done to rank them with the Dwyka beds of South Africa and other examples in Australia and India as evidence of ice action of the glacial type.

In order to make profitable use of the remainder of a half-year's leave of absence, Mr. Woodworth will on the advance of the rainy season in Brazil proceed southward to the coast of Chile via Buenos Aires, Neuquen, and the Lago Nahuel Hupi route across the Andes to the coast at Valdivia for the purpose of studying the phenomena of elevated shore lines northward to Valparaiso, not so much from the point of view of a reëxamination of the well-known evidence of uplift as from that of the nature of the elevatory movement whether *en masse* as Charles Darwin supposed or by repetitive faults such as recent field studies have brought to light in North America.

A MEETING OF THE GEOLOGICAL SECTION of the New York Academy of Sciences was held on May 4 in the American Museum of Natural History, New York City. Papers were read by Mr. J. E. Hyde, "The Waverly Problem"; Dr. George F. Kuntz, "Notes on Recent Mineral Occurrences"; Professor W. O. Crosby, "Beach Cusps and Related Phenomena."

REPRESENTATIVES OF TWENTY of the state geological surveys meeting in Washington, May 13, organized an Association of American State Geologists. Provision was made for an annual meeting and the appointment of various committees for the transaction of the business of the association. H. B. Kümmel of New Jersey was made President, H. F. Bain of Illinois, Secretary, and J. H. Pratt of North Carolina was appointed to act with them, forming an executive committee. Messrs. W. B. Clark of Maryland, I. C. White of West Virginia and J. H. Pratt were appointed a committee to investigate the distribution of documents by the various surveys. J. N. Clarke of New York was appointed to represent the state geologists on the general committee on nomenclature now being organized, with Samuel Calvin of Iowa and E. A. Smith of Alabama as associates. The following resolution was unanimously adopted:

Washington, D. C., May 12, 1908.

Whereas, our country and the sovereign states composing it now face serious problems relating to the preservation of our national resources, and,

Whereas, these problems,—of wisely administering our forests, our minerals, our soils, our water resources,—are tomorrow to be the subject of a conference between the governors of the various states and the President of the United States, and,

Whereas, we deem a contour-topographic map of our country so necessary to the intelligent solution of these and equally important problems,

Be It Resolved, that we more earnestly ask of the State and Federal authorities in conference assembled their support in securing such a map, and, since the State and National interests are here so closely one, we most respectfully suggest: That State and Federal appropriations for topographic surveys be increased, and that more immediately the Federal appropriation be increased for this work to meet the State appropriations now available.

Be It Resolved Also, that a copy of these resolutions be presented to said conference of the governors with President Roosevelt with our greetings and respect.

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